BELL

VENTILATING BUILDINGS

Honble J. A. Dix —
from D. L. Dix.

August, 1849.

THE

PRACTICAL METHODS

OF

VENTILATING BUILDINGS,

BEING THE

ANNUAL ADDRESS

BEFORE THE

MASSACHUSETTS MEDICAL SOCIETY,

MAY 31, 1848.

WITH AN

APPENDIX,

ON

HEATING BY STEAM AND HOT WATER.

BY LUTHER V. BELL, M.D., LL.D.

HONORARY MEMBER OF THE NEW YORK STATE MEDICAL SOCIETY, ETC.; PHYSICIAN AND SUPERINTENDENT OF THE M'C LEAN ASYLUM FOR THE INSANE, A DEPARTMENT OF THE MASSACHUSETTS GENERAL HOSPITAL.

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ADVERTISEMENT.

As stated in the title, the following pages constituted the anniversary address before the Medical Society of the Commonwealth, and as usual, were printed in one of the volumes of its "Communications." I have taken advantage of the type, to have a small number of copies arranged and printed for distribution to private friends, and to some public libraries in this vicinity, where the record of a present condition of facts in any of the sciences or arts of life, may be preserved for the interest of those who succeed us.

No person can be more sensible than I am of the incongruity,—almost the absurdity,—of an *oration* or address on so homely and unrhetorical a topic as ventilation. I was moved to select it in preference to the many more ornamental and facile subjects of medical science, because it appeared to me to be of the most pressing present moment, as well as of absolute general novelty in our country, and because my attention, from my connection with some public institutions, had been turned for many years to its practical details.

I have directed a view of this Asylum, engraved for another occasion, to be placed as a frontispiece, because it served to illustrate a condition of the ventilating provisions described in the Appendix (the point of egress at one of the chimnies surrounding the dome), not presented in either of the diagrams of the fourth Plate.

L. V. B.

McLean Asylum, near Boston,
July 4, 1848.

ON THE

PRACTICAL METHODS

OF

VENTILATING BUILDINGS.

Mr. President and Gentlemen,

On this anniversary occasion, when so large a proportion of the almost thousand associated members of the medical profession of this ancient Commonwealth, has come up to this metropolis, for the mingled purposes of fellowship, of festivity, and of such instructive suggestion, as "the hour and the man" may furnish, — upon me has fallen the honorable duty of providing some topic for your reflections, and leading your thoughts in the direction of some not unprofitable, nor useless, inquiry.

It is but once in the reach of a single individual's whole life, however prolonged, that to him can be expected to fall the high privilege, the profound responsibility, of having his living voice touch the living ear of the assembled profession of a great commonwealth. I feel that the highest

ambition which fills my mind in this office, as well as the strongest manifestation of respect to the character, attainments, and tastes of an audience like this, is, that every sentence uttered should contain a fact, — a useful, available, practical fact, — or some just, candid, reasonable deduction from an undoubted basis. Willingly would be foregone all the honors and applause which the most successful literary or rhetorical effort could elicit from a gratified, but unprofited audience, could I but feel that you, or that great community of which you are, in some measure, the representatives, as well as the protectors, may not be unbenefited by my well-intended service.

In accordance with these impressions of what is due to this Society, — to this occasion, — I have selected as the topic of my address, the directly practical or mechanical applications of the science of ventilation, or rather the division of it which has been termed by writers *internal* ventilation, as contra-distinguished from *external*, in the scope of which latter is comprised the means by which towns, cities, or even large territorial districts, are rendered more salubrious, as respects the atmosphere, and its contents, appreciable or subtle.

Under the term, ventilation, philologically not very accurate or comprehensive, is intended that science, with its connected arts, formed by contributions from almost all the other natural sciences, physiology, chemistry, pneumatics, mechanics, and others, through the agency of which, adequate, per-

fect, and certain supplies of pure atmospheric air are furnished and continued, under ascertained conditions of heat, moisture, and motion, in edifices or apartments in which the air would become vitiated and destroyed, by respiration, combustion, or other oxygen-removing processes, or made unhealthful or disagreeable by admixtures of suspended or combined foreign matters.

Under recent advances in this science, a true ventilation is designed, also, to comprehend the acoustic relations of the air, as well as its more palpable and material admixtures.

At first thought, it may appear somewhat fastidious, or even unphilosophical, to regard merely unwelcome sounds, recognized by the ear alone, in the light of offensive impurities, or rather as disagreeable additions to the medium in which we live and intercommunicate, yet no explanation will be needed by a body of medical practitioners, residing, in part, in large towns and cities, for considering the means of averting, or obviating, the annoyances and injurious irritations of painful sounds, in the same category with the disagreeably offensive, or actually malarious contaminations.

The physician in the densely populated and industrial community, must have often recognized the discomforts and serious injury from the former, to the patient on the bed of sickness, with keener regret, than the noisome or pestilential emanations of the air, as less susceptible of being counteracted or nullified by ingenuity and care.

It is a gratifying coincidence, which will most fully develope itself as the various modifications of the ventilating system are brought forward, that the improvements which have so fully satisfied the requirements of health and comfort, as respects respiration and purity to the senses, also meet the necessities of the ear. We shall see that under the complete arrangements for atmospheric supplies, secured in modern provisions, this rather more remote requirement is completely fulfilled, — a necessity of the highest moment, as regards that somewhat extensive class of edifices, assembly rooms and halls, in which distinct and easy elocution, or the completest delivery and reception of musical sounds and literary compositions, are the principal desiderata.

Under the aids of *forced* ventilation, or that in which an independent motive power is relied upon, all varieties of system require, as a condition of their full effect, the avoidance of any direct communication with the outside air, by the closure of all windows or openings, which might admit foreign, or confuse designed vibrations. Hence, the purest efforts of speech and music are transmitted to the audience, unmutilated and unmixed, and with the least labor and pain on the part of the vocal performer. The most refined enjoyments of the musical art, the most persuasive and overpowering effects of eloquence, and the full weight of instructive attempts, thus unite their claims for consideration, in this useful science, as well as the

more immediate and pressing demands of body and mind, for exemption from disease, prolongation of days, and the highest intellectual and moral exercises.

It has been customary with every writer and teacher on ventilation, to commence his labors with a more or less thorough elucidation of the chemistry of respiration, and the other physiological relations of that all-essential process of the animal economy. That these are immensely consequential, no one would think of doubting, and well worth all the laborious experimenting and research which they have so long and so faithfully received. The very fact, that a half of the machinery of the human body, measured either by its capacity or its complexity, is devoted to the function of ventilating the blood, by processes essentially mechanical and chemical, demonstrates the rôle which the air plays in the support of life, and can hardly be overestimated. But, believing with Mr. Brande, and other distinguished philosophers, that neither chemistry nor physiology can afford us much direct aid in determining the quantity or conditions of air needed for the uses of men in habitations, — that, like food or clothing, it is a practical question, to be solved only by experience, I do not propose to dwell upon these indirect subjects, already so well understood by the profession, and upon which the fullest and most trustworthy authorities are accessible at every hand.

Indeed, it seems to me, that the experimental investigations which are to aid us in applying results to useful purposes of existence, are only those in which, (to use the words of Dr. Reid,) men in bodies and aggregations are regarded in the light of matters for chemical examinations and trials, while their habitations, from palaces to prisons, are the pieces of apparatus, in which the analyses of results are to be wrought out, by patient and oft-repeated tests.

Nor do I intend to open to any considerable extent, the pathological considerations, — the character and causation of the multiform diseases, connected with that deterioration of the medium of life, which it is the object of ventilation to prevent and to cure. This connection has grown into an importance, under "this new era of sanatory reform," as it has been so well called, its bearings have been so fully studied, that to do adequate justice to its claims, the original evidences from the experience of the old world, must be examined by volumes, not in abstracts.

An able writer on Military Engineering, observes in relation to his art, that facts, which are the deductions of long and tried usage, hold in many instances, the place of principles. This axiom appears equally applicable to the practice of ventilation. An art made up of the contributions of so many departments of knowledge, involving so many difficulties in these combinations, and subject to so many modifications, almost as numerous, in fact,

as the individual examples, can be safely grounded only on experience. Perhaps in no other instance of the application of science to the arts of life, has it been found so unsafe to act from pure scientific deduction, or where trial would more annoyingly demonstrate, how widely fluids, whether gaseous, or liquid, act in practical usage, from what they seem bound to do, in legitimate accordance with theory.

I would not be thought to undervalue an abstract knowledge of the sciences, involved in the theory of this art, but only require that the practical application should be studied and determined, rather in the light of antecedent successful and abortive trials, than on any a priori reasoning.

Sir Humphry Davy, in the zenith of his fame as a chemical philosopher, utterly failed in ventilating a single assembly room, under the most favorable circumstances. Men of infinitely lower attainments, profiting by a long series of examples of all grades of perfection, are now able to succeed under the most complicated and embarrassing difficulties.

The means of ventilating buildings have been brought to their present advanced and successful state in Europe, rather by successive steps — by a gradual gain of new points upon old, than by new discoveries or inventions. In this mode, will the art go on to a still higher grade of completeness, and hence the necessity of a thorough understanding of what has been done, to avoid the repetition of ex-

periments, which may have been tried and have failed again and again. Viewing our object in this strictly practical light, and believing from its very nature, that no marked novelty can ever be expected to replace all that has already been attained, as it is not unfrequently the case, in certain mechanical ends, I propose, as the most practical and available method to aid a community like ours, in search of this auxiliary to health and comfort, to bring forward, and briefly explain the plans which have stood the test of adequate trial, in various countries, and under various conditions of climate and occasion. From these will then be separated the points and principles which appear to be ever present and essential. The way will thus be opened for the means of judging of the relative value of the modes of bringing about satisfactory results, which are found to be constant, and the circumstances which determine an election of individual varieties, among the many ways of accomplishing the same end.

I am aware that the suggestion, that there is no well founded reason to believe that any of the modern improvements in ventilating are to be considered in the rank of new discoveries, will strike many persons, who have only read the books of certain claimants of original methods, as indicating an uncharitable disposition to detract from the merits or honors of origination. A disinterested investigator, removed from the influences of national, partisan, or personal partialities, I cannot but think, on fair adjudication, will feel full confidence, that the ad-

vanced specimens of modern ventilation are due only to the unbounded opportunities of carrying out well recognized ideas of long standing. Dr. Reid's plans, which doubtless have been regarded as new, by those deriving their sole information from newspaper paragraphs, or critical reviews, will be found, when fairly analyzed, only the fruit of well understood principles, applied with very advantage of mechanical skill, and unlimited expense, occasionally carried to an extreme of refinement, fastidious and finical.

Any one who will run over the annals of science, can go back to the very fountains of medicine for the earliest recognition of the importance, and indeed, for some of the practical methods of this department of hygienic and sanatery protection. Moses appears to have comprehended the nature and importance of external ventilation, as shown in the geometrical and systematically arranged encampments of the children of Israel. Two thousand years ago, Hippocrates treated of the value of a pure atmosphere, its influence on life and disease, and laid down rules for securing this object, with a clearness and truth, which demonstrated that his wonderful tact and observation, so many centuries before the constitution of the atmosphere, or the chemistry of respiration were dreamed of, had given him the most correct and practical notions of its importance.

Celsus, in his instructions as to the treatment of fevers, directs the air of the patient's room to be pu-

rified by a fire lighted in a fire-place — involving the same principle of rarefaction as Dr. Reid's Parliamentary ventilation. Agricola, in the sixteenth century, appears not only to have recognized the necessity of introducing pure supplies of air artificially, but has suggested, or at least recorded for our instruction, the very means for producing an upward current of vitiated air, by fire applied to the exterior of a metallic tube, through which the air was thus speeded by diminished gravity and partial vacuum, long after adopted by Davy, and, as we shall have occasion to observe, forming the basis on which various commissions in modern times, have ventilated the most important public edifices.

The real constitution of the atmosphere, we know, was a mystery, until analyzed and its action on the system developed, by Priestly, Scheele, Black, Lavoisier and Davy, and that brilliant galaxy of chemists and physiologists, which flourished towards the beginning of the present century. But its mechanical properties, and its practical relations to health and life, were as well understood and as well applied half a century before. In 1727, Dr. Desaguliers, and soon after Dr. Hales applied pumps, and in years subsequent, centrifugal wheels or fans, and flues urged by fires, directly or collaterally. In fact, most of the means, which ingenious men manipulating with a fluid, the mechanical properties of which were perfectly understood by them, would naturally adopt, were actually introduced to accomplish movements and results, which were alike manifest to them. Pris-

ons, shops, and legislative halls, hulks and hospitals of all kinds, were provided with apparatus to give them pure and healthy air, and our present plans are but little more than the ruder schemes of the old, and quaint projectors and philosophers, verified under circumstances of more enlightened society and wider means.* Many of these enthusiasts in ventilation only lived before their day, and it is truly painful to read, that men, the correctness of whose ideas in science, and the elevation of whose philanthropy entitled them to respectful gratitude, were obliged to dance a fruitless attendance, on sneering and ignorant functionaries of government, or even had plans, which in principle were equal to those now in successful use in our best examples, turned into ridicule and rejected, by the mischievous interference of the mere menials whose tempers or whose interests were not suited.†

I am prepared to assert, after a diligent recurrence to the original accounts of these men, that the essential points of all modern contrivances, except the single one of producing an exhaustion by the admission of a jet of steam, were all anticipated in their writings. No man of our own age, in my opinion, can sustain any higher claims to original suggestion, as regards internal ventilation, than should be accorded to ingenious and well matured

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* Fig. 1, Pl. 1, represents a method of exhausting air from mines, copied from a drawing in the Phil. Trans. for 1665. The fire in the grate produces a current through the box, *b*, connected with the mine.

† See Desagulier's Philosophy, vol. II. p. 561. Fig. 3, of the same plate, represents the system invented by Mr. Sutton, an eminent brewer in London, and much employed about the same period. The foul air flues from the hold, were admitted under a ship's coppers, or other fire.

adaptation, more completeness of detail and higher refinement of results.

The English, since 1835, in consequence of the destruction, by fire, of their House of Commons, and the determination to construct a national palace for the Legislative Representatives of the kingdom, on a scale of magnificence and completeness, unapproached in modern architecture, have devoted, under the patronage of Government, and the impulse which a general turning of attention to a subject of universal utility would naturally give, a great amount of research and ingenuity to the means of ventilation of all kinds of habitations of men, on land and water. The accounts of many of the most complete of these undertakings, drawn up with the utmost minuteness of detail, and the record of their operations verified with mathematical certainty, are before the world. Their worth as contributions to the cause of science and philanthropy, is not to be undervalued, yet it is not to be concealed that, thus far, there is no evidence that the British attempts have proved more advanced in science or success, than those reached by their neighbors across the Channel, under the guidance of Gay-Lussac, Thenard, and others, who have pursued their investigations and applied their results, in that quiet and unobtrusive, yet thorough research, which so eminently characterises the labors of the French *savans* in every field of scientific pursuit.

While the opinion is thus confidently offered, that no great or original discovery can be justly

asserted in modern ventilation, a denial which detracts little or nothing from the honorable claims of those, whose skilful adaptations are as useful as if they had the element of originality in them, it is humiliating to be obliged to confess that our own country stands lamentably in the back-ground, in this important provision. It would be difficult, if not impossible, to point out half a dozen specimens of buildings, ventilated in accordance with the full application of principles, tested elsewhere successfully for years, although it must be accorded that in view of our climate, our habits of life, our great disposition (beyond example) to constant and protracted accumulation of numbers, for purposes of business, instruction or amusement, by night and day, no community in the civilized world, more really and urgently requires the aid of the ventilating art, so far as regards its important ends of comfort and health.

Our common school system, in which minds and bodies are moulded at the plastic period of life into forms to be retained, and I may say without trenching on the domain of new theories or speculations, perpetuated, offers a more urgent appeal for attention, than can be imagined in any old world institutions.

We, too, are becoming rapidly a manufacturing people, to follow in the awful footsteps of our prototypes, the world over, unless we can do that most difficult of moral feats, profit by the unfelt experience of preceding races. We are doing what

the world has no historical parallel of, in building towns and cities. A few men of giant energies, of boundless faith, of far-seeing calculation, sit down in the counting-rooms of this city, with a surveyor's sketch, and a few engineers' levels. They decide that a town shall be built — a manufacturing city erected. Straightway, and almost like the falling, opening, raising, changing scenes of the theatre, huge brick palaces arise, streets in long perspective of shops, schools, houses, side-walks, begin to stretch themselves out from a thousand nuclei, to meet the new formed elements in exact symmetry, like the points of ossification in the growing embryo. Churches point their spires to the skies, in all the beauty of Gothic tracery, or plant their firm columns of stone, in all the solidity of Grecian art. In short, what the conquerors of the world have been lives and centuries in designing and accomplishing, is called into existence by our merchant princes, almost with the wave of Prospero's wand!

Would that the same prophetic and far-seeing vision, which pierces so clearly into the distant future, as to warrant these unbounded outlays, — the same forecast, which casts its bread upon the waters with so lavish a hand, in the confident expectation of a bountiful return — which boldly cuts down hills and fills up vallies to accommodate the hundred thousand inhabitants, presenting themselves in the misty future, while the grass is still green in the projected avenues, — would that it could, at the same time, foresee and prevent, the

disease, the death, the misery, the moral, social, as well as political ills, which appear, upon the best of evidence, to go hand in hand with neglect of plain sanatory precautions, — and realize the illustrations unnumbered from experience past, which tell with demonstrative certainty, that moral and social degradation are indissolubly linked with disobedience of nature's laws.

I blame not these founders of cities, that they have paid but little regard to hygienic and sanotary measures. It is glory enough to build cities, — it is too much to expect the same minds which can grasp all the elements essential to these great undertakings, in a commercial point of view, should comprehend all the mysteries of typhus, struma, or contagion, and the relation of these to ventilation, sewerage, and water supply. It is for our profession to step in at this point, and to guard the rights of generations yet unborn, in these respects, and the wise interest, the sagacious foresight, the honorable ambition for unmixed success, will guarantee the co-operation of the builders of cities, whenever they are convinced of the reality of the evils, and that they are susceptible of prevention and relief.

The "ghastly bills of mortality," as they have been termed by an English statistician, (under some overlooked or mistaken modifying circumstances perhaps,) of one of our new cities, the prevailing impression of the unhealthfulness already of our lately populated manufacturing towns, call aloud

to the medical profession to look at the growing evils of hygienic neglect, full in the face, and if they require a plenary and decided remedy, however costly, it will not be long in being found.

It might not be out of place, were it of any probable utility, to inquire into the causes of this want of advance generally, in an art so universally admitted, in language, to be important. We scarcely ever read the description of a new assembly room, or theatre, or hospital, or penitentiary, in which we do not find laudatory and congratulatory notices of the excellent provision for ventilation. This provision, of course, in ninety-nine cases out of a hundred, is nothing more than some small holes left in the ceiling, the inefficiency of which has been notorious for a hundred years. Still such a general recognition is sufficient to prove a general necessity.

Our inefficiency cannot be from want of acquaintance with what has been done in other countries, more advanced in the arts of living, since the books detailing the necessities and the modes of meeting them, in the most authoritative manner of investigation, are known to every scientific inquirer, and are to be found in every considerable library.* We must rather ascribe our backwardness to the same general causes, which have kept architecture, both as a useful and an ornamental art, at so low an ebb, throughout our country. One of these is, that

* Appendix D.

for the moderate capital we have to devote to such purposes, we have an undue desire, a morbid ambition to produce more of splendor and show, than is compatible with permanence, completeness of interior arrangements, or regard to hygienic considerations. Anything out of sight, like the deep and enduring concrete foundation, the inverted arches of support, designed to meet the possible failures of succeeding centuries, or the concealed arrangements needful for a thorough and universal ventilation, which must commence almost at the corner stone and be kept in continuous design until the last finish, would be struck out, in a vast majority of instances, from the architect's specification, (if he dared to suggest them,) as an expense which might be saved without being felt. On the other hand, the dome, the spire, the columns, the pilasters and balconies, some of which, as mere ornamental appendages, could be added at any time, now or a century hence when funds might be more abundant, or never, would be adhered to as essentials, as indispensable.

Despite the science and mature experience of a thousand European attempts, fully and exactly detailed in the unmistakable language of description and pictorial representation, our Building Committees would assuredly, after making their personal inquiries among the hundred interested patentees or dealers in new furnaces, chimney-tops, revolving turn-caps, and the like, conclude that, amongst so many *practical men*, promising in their

advertisements and circulars, so many cheap and effectual methods of doing that which the old world artists consider so difficult and expensive, some ready measures would turn up, when their part of the duty was finished.

The most costly edifice in the northern states, just finished with eternal granite, on foundations based in the ocean, at a cost of a million of dollars, is an illustration, an abundance more of which could be easily adduced, were not the task an invidious one. Proposals for heating and ventilating were advertised for, after the building was finished!

I would not, however, be understood to criticise, with undue severity, an unacquaintance or neglect, for which our profession would certainly be obliged to assume a fair proportion of the responsibility. It is to be considered, that ventilation, however appreciated by the scientific, is only gradually forcing itself into the notice of ordinary minds, to whose practical experience a predominating weight of deference must naturally be paid in a new country. We have yet scarcely a class of architects, whose character or attainments are sufficiently acknowledged, to allow their judgment and taste to overrule the occasionally absurd phantasies, or conceited presumption of Building Committee majorities.

A new country, engaged in burning up the original forest as rapidly as possible, in laying deep the basis of civil and political institutions, in taking care of things indispensable to actual existence,

cannot be expected to provide for all present—much less future and contingent evils. Had those who laid out the three-mountain city, by taking the cow-paths, or no more positive indications, as their guiding lines, seen that in a couple of centuries it was to be a great metropolis, yielding all the moral and social good and evil of a great city, how widely different would have been the expanse of their views, and the modes of applying them in practice!

Could those now on the stage, see the hundred and fifty thousand of the population of it, and its suburbs, quadrupled in a hundred years, how much ought they to learn by the present condition of analogous cities of the old world. What has been will be; and we can read no plainer augury of what we are to be socially, and municipally, than to apply the lessons presented by our mother country. Sir Christopher Wren, after the ground was all laid open in London by the great fire of 1666, matured and delineated a plan, lately rescued from oblivion and published, by which that city was to be constructed, as regards the great provision of pure air to its inhabitants, so as to secure its healthfulness to all future time. Could the citizens then on the stage, have had that faith, which now seems to have been so obviously irresistible, what myriads of lives, what a boundless extent of disease, moral wretchedness and misery, would have been saved! Yet in New England, we see thousands of houses constructed on the marine marsh, with scarce an inter-

vening yard of gravel, perhaps not a foot, between highly finished and furnished mansions, and that awful quagmire of decomposing animal and vegetable remains, the emanations of the pestiferous gases from which, penetrate the closest interior, and leave the stain of their chemical action upon the valuables contained — still more is it to be dreaded upon the bright faces and active lungs of the youthful inmates, called into existence, in habitations suspended over this sea of corruption!

Besides these natural obstacles to sanatory provision in a new country, we have undoubtedly indulged the fallacious hope or impression, that our peculiar climate, or abundance of space, would save us from the consequences of those violations of sanatory laws, elsewhere followed by the direst penalties; and as every new settlement is pronounced salubrious, until disease and death afford undeniable proof to the contrary, so we have waited to have an overpowering weight of unequivocal evidence of the injurious influences of neglected ventilation, before it is deemed worth while to act. These evidences have been slow and gradual in coming. Our cities have not been much compressed with living masses, our penitentiaries, almshouses, and hospitals, have been too few and on too small a scale, to present the lesson so as to be clearly read. Manufacturing establishments, where hundreds are engaged in labor within reach of each others' inhalations, with their crowded boarding houses, in which the operatives are almost piled at night, so that only a few feet of

space separates the lungs of each denizen of a large town, constitute emergencies of but yesterday. Still more, the rapid growth of many of our commercial towns, increasing from hundreds to thousands, as it were, in a night, carrying them, with no intervening space for adaptation and experience, from the rank of mere villages to great cities, has given them no warning, nor led to any protective measures against the physical or moral evils, which are incident to these "great sores on the body politic,"* whether in the new or old world. In short, the call to alleviate and provide for the consequences, necessary and unavoidable, of great accumulations of human beings, poverty, filth, disease, and death, comes at once, without premonition. The imperious necessity, and the skill, intellectual and mechanical, to meet its pressing demands, follow in that slow succession, which leaves thousands of victims in the track.

Our present demand for internal ventilation as a domestic necessity, has also been strongly influenced by the change in the modes of heating, within a few years. The roaring fire-place, built with an open-mouthed immensity of voracity, as if the struggle were to aid in getting rid of the primeval forest,— in which the Roman poet's verse was practically illustrated in every household,

> ——— ligna super foco,
> Largė reponens ;

—has been replaced by furnaces, stoves, air-tights,

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* Jefferson.

of all forms and shapes which caprice or ingenuity has invented. The sweeping flood of air, which carried with it, in its course, the most liberal in-draughts of the pure breath of heaven, compensating for the abduction so largely of the warmed air itself by the radiated caloric of the blazing pile, has been dammed up, and that almost entirely. The re-respired, roasted, ill-conditioned air of the dwellings even of the rich, is the result of a parsimonious economy, which strangely and absurdly exists as to this, in a thousand instances, where comfort and luxury make no other sacrifices to saving. *Fuel saving* is one of the cardinal virtues, in the housekeeper's creed, while provision saving, or pure water economy, would be scouted as the height of meanness, or uncalled for self-denial.

Be all the circumstances of defective sanatory provision, (of which ventilation is surely one of the most pressing,) what they may, there can be no question that the results of impure air, are upon us, in all the malignity and infection of the old world in degree; and even since we last met, and in our midst, amongst our associates, the Angel of Death has hovered around, sending his fatal shafts to pierce some of the noblest sentinels of our ranks, and warning us, that if we would improve the sad experience of older countries, we may not longer delay our defensive preparations against that most broad spreading missile of destruction, poisoned air.

In that unfortunate over self-estimation, which, happily, is now beginning to be felt and acknow-

ledged as having formed almost one of the characteristics of our national identity, we are accustomed to speak of ourselves as a long-lived people, inhabiting most salubrious climates, and advanced to that grade of civilization and general education, in which the laws of nature were recognised and obeyed, as well as the laws of revelation and of the social compact.

Reposing self-complacently in a presumption of this kind, (unfounded, it is true, as statisticians amply demonstrate, as far as health and vitality are concerned,) we have felt less called upon, than communities conscious of their own deficiencies, to search out and correct any of those prejudicial influences in hygiene, which bear upon the probability of life.

This is not the occasion to examine the important question, how far, as New Englanders, we compare with other communities in life and health. The simple fact that the tables of life probabilities, deduced from the experience of the crowded, poverty oppressed nations of the old world, the victims of so many circumstances, moral and physical, calculated to influence health and shorten existence, are practically found not inapplicable to a New England population, at the present time, casts a most melancholy foreboding upon the prospects of coming generations, when all the health-influencing concomitants, whether of penury or luxury, of a dense population, are added to our already prolific life-abridging influences.

An associate of this Society, Dr. Jarvis, in a report, as Chairman of the Committee of the American Statistical Association, appealing to the Legislature at its last session, for a sanatory survey of the Commonwealth, demonstrates this important fact so conclusively that I cannot forbear to leave the proof on record. *

How wide spread and active one of these life-shortening causes, the daily, hourly inhalation of vitiated air is, may be deduced most conclusively, though from its nature, only generally, from the universal

* We may be a favored people in many respects; but, in comparison with some other nations, we do not enjoy the highest degree of life.

According to the best calculations, the average longevity of the people of this state is less than in Sweden, France, and some counties of England; and it seems to be less here now than it was in the past generation.

The average age of all who died in Geneva, Switzerland, from	1814 to 1833,	was	40 years	8	months
Massachusetts from	1842 to 1845,	"	33 "	0	"
" in	1842,	"	34 "	9	"
" "	1843,	"	33 "	10	"
" "	1844,	"	33 "	9	"
" "	1845,	"	30 "	3	"
The average age of all whose deaths are recorded in					
Massachusetts, in	1842,	was	34.9 years	9	months
"	1845,	"	30.9 "	3	"
Concord,	1779 to 1808,	"	39.9 "	7	"
"	1809 to 1842,	"	36.9 "	0	"
Dorchester,	1817 to 1829,	"	33.9 "	11	"
"	1830 to 1843,	"	31.9 "	2	"
Boston,	1811 to 1820,	"	27.7 "	3	"
"	1831 to 1840,	"	22.7 "	9	"
The average age of the living,		was in			
England in	1841,		26 "	7	"
Massachusetts, in	1840,	was	25 "	10	"
United States in	"	"	22 "	8	"
And in the northern states, including New England, New York, Michigan, Wisconsin, and Iowa,			23 "	3	"
In the middle states, south of the above, and north of North Carolina and Tennessee, - - - - -			22 "	0	"
In the states south of the middle, - - - - -			19 "	5	"

experience of men in all places. Numerical facts, collected with cautious observation, and over long periods of time, justify exact conclusions, as respects those bodily conditions, which language is precise enough to specify. Yet how few, how insignificant are those truths on this subject, capable of being exactly recognized and statistically recorded, compared with the infinitely wider spread, more penetrating evils, which can be conveyed only in the words of general impression and personal conviction.

When the laborer is drawn from the well, the vat, or the mine, asphyxiated by immersion in carbonic acid gas, or is smitten with instantaneous death, by the noisome burst of phosphureted or sulphureted hydrogen, or ammoniacal gases of a Parisian sewer, we see an extreme exhibition of this causation, in palpable and undeniable prominence. In the deadly typhus of jails, emigrant ships, or other dwellings of numbers and misery, we can as little doubt the fatal consequences of impure air. When we examine the immense mass of sanatory documents, collected under the Parliamentary inquiries of the British government, detailing the connection between the damp, unventilated lanes and cellars of Liverpool and Manchester, and the prevalence of struma, phthisis, rachitis, fevers of all types of malignity, from simple ephemera to deadly typhus; in fact, of almost every form of acute or chronic diseases, which constitute the great outlets of human life,

we recognize an equally unbroken link in the chain of cause and effect, antecedent and consequent.

The experience of the celebrated Black-hole at Calcutta, in which one hundred and forty-six persons were confined over night, within a space of about five thousand cubic feet, showed the singular fact, that the deaths of all but twenty-three from immediate suffocation, were not more directly the result of vitiated air, than that of most of the survivors within a few weeks after, of putrid fever.

Dr. Southwood Smith, in his testimony before the Commission for inquiry into the state of large towns and populous districts, observes, that it is no exaggerated statement to say "that the annual slaughter in England and Wales, from preventible causes of typhus fever, which attacks persons in the vigor of life, is double the amount of what was suffered by the allied armies in the battle of Waterloo." Add to this the appalling fact, that each death from typhus implies from seven to twelve persons dragging out a long and painful sickness, under circumstances of the greatest privation and misery, and we shall realize the terrible extent of suffering within the power of relief.

Yet how little do we comprehend of the extent of the evils of the depraved *pabulum vitae*, atmospheric air, from these palpable, tangible illustrations. Dr. James Johnson, in his striking and impressive manner, remarks, in his Diary of a Philosopher, in discoursing of the evils of impure air, that "ague and fever, two of the most prominent

features of the malarious influence, are as a drop of water in the ocean, when compared with the other less obtrusive but more dangerous maladies, that silently disorganise the vital structure of the human fabric, under the influence of this deleterious and invisible poison."*

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* (*Extract from the Report of the Registrar General.*)

"Out of an equal number of males living, there were three deaths in London for every two in the healthy counties. Out of 1,000 boys under five years of age in Surrey, and 1,000 in Sussex, 48 and 50 died annually; out of 1,000 in London, 93 died annually. The mortality of children under five years of age, is twice as great in London as in the adjacent counties, including several towns.

"The excess of deaths in London is not the result of climate, for the climate differs little from that of surrounding counties; and some of the London districts are not more unhealthy than many country districts. Take Lewisham, for instance, comprising Blackheath, Sydenham, Eltham, and Lewisham itself. The annual mortality of females was 16, of males 18, in 1,000.

The actual deaths registered in London during the seven years 1838—44, were - - - - - - - - - - - - -	342,000
If the mortality during the period had not been greater than in Lewisham, the deaths in London would have been about - - -	244,128
Excess of deaths in London, - - - - - -	97,872

Here are 97,000 deaths in seven years, from causes peculiar to London. Other districts may be taken in the place of Lewisham, but the result would be the same.

"A considerable part of the population of London is recruited from the country; immigrants entering chiefly at the ages 15 to 35, in a state of good health. The sick and weakly probably remain at home; many of the new comers too, unmarried, when attacked in London by slow consumption — the most fatal disease at the ages 15 to 35 — return to their father's house to die; so that the mortality of the great city is made to appear, in the returns, lower at those ages than it is. If we take children under five years of age, where neither these disturbing causes nor occupation interfere, the deleterious influence on health, of London in its present state, will appear undisguised in all its magnitude.

The deaths registered in London under 5 years of age were - - -	139,593
The deaths, if the mortality had not been higher than in Lewisham, would have been - - - - - - - - - - - - -	80,632
Excess of deaths in London among children, - - - - -	58,961

The British Government has long evinced the most high-minded and liberal policy, fully repaid by the returns to human health and happiness, of aiding science in its researches, as respects those great points of inquiry, which, however consequential in their bearings, can, from their magnitùde and complexity, only be elucidated on the largest scale, and by authority. Among the immense mass of facts, bearing on man and his diseases, ever in the process of collection, and accessible to proper examination, are the reports of the army and navy medical officers, on the sickness and mortality of troops stationed around the globe. "These," remarks Mr. Hood, "prove most clearly the immense effect upon human life, produced by small and almost inappreciable differences in the quality of the atmosphere. For, in the same class of persons, performing the same duties, and placed as exactly as possible in the same circumstances, the average mortality varies in different parts of the world, from 1.57 per cent. to 66.83; or the mortality is nearly forty-nine times as great in some localities as in others."*

"Here are more than 58,000 children destroyed in London within seven of the last ten years."

Ninety-seven thousand deaths in seven years, from causes peculiar to the "comparative health" of London! Fifty-eight thousand children destroyed in London, within seven years, by removable morbid agencies! Three deaths in London, where there might be two! The chances of infant life in London, reduced one-half below even that very unsatisfactory standard elsewhere realized by sanatory arrangements!

* These reports contain the results of twenty years, and present the follow-

Did the hour or the scope of my design permit the general consideration of the effects, immediate and remote, of the pulmonary imbibition of the gaseous agents into the human constitution, under all their forms and combinations, how could I so powerfully illustrate my subject, as by bringing to your minds the great discovery of our age, connected so intimately with the name of a distinguished associate of our number, — a discovery already world wide, in the glory reflected on the land of its birth, upon our metropolis, our profession, as it is in the blessings it has conferred upon our race — a discovery, which, with vaccination, forms the two great triumphal columns in the world of medical science, — the *annihilation of pain by the inhalation of the vapor of ether?* If in our hasty illustrations of the influences of the gaseous mixtures of the air we breathe, upon health and life, we see disease, pain, death, horror, in the inspiration of the pestilential vapors of many names — in this we see health, relief, blessing, extasy! If those bring with them,

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ing per centage of deaths per annum, among white troops only — native troops being excluded:

	Per cent.		Per cent.
British Guiana,	8.4	Sierra Leone,	48.3
Trinidad,	10.63	Cape Coast Castle,	66.83
Tobago,	15.28	St. Helena,	3.3
Granada,	6.18	Cape of Good Hope,	1.37
St. Vincents,	5.49	do. Frontiers,	.98
Barbadoes,	5.85	Mauritius,	2.74
St. Lucia,	12.28	Ionian Islands,	2.52
Dominica,	13.74	New Brunswick,	1.47
Antigua,	4.06	United Kingdom,	1.4
St. Kitts,	7.10	Canada,	1.61
Jamaica,	12.13		

"blasts from hell," this, this truly "breathes airs from heaven!"

Proceeding then, in that strictly inductive method I have intimated as being essential to reap practical and applicable advantage in this art, I shall endeavor to sketch a brief but substantially complete account of the modes of ventilating various kinds of habitations, selected from the most successful and well tried examples. Having no particular preferences for, or convictions of the superiority of any given system by itself — confident that various considerations may render, sometimes one, sometimes another the more eligible, I shall not confine myself to a few methods, but endeavor to point out the prominent features of all the really tried arrangements.

I hardly need explain or apologize for the fact, that only a mere outline, an unclothed skeleton as it were, of the subject, can be presented within the compass of an hour, compelling a resort to pages omitted, to notes and appendices, for much of the exact and practical details, from which alone a clear understanding and ready adaptation of the labors and experience of others can be secured to our own community. It is fortunate that the precedent of so many of my distinguished predecessors, on this occasion, warrants a departure from what is written, which under other contingencies, would be so obnoxious to just objection. In this, as in most mechanical descriptions, knowledge, to be available, must be exact, precise, and specific; and the aids

perhaps of diagrams, mathematical formulæ, tabular deductions and results, and other matter not capable of being presented orally — addressed to the eye rather than to the ear — are essential to a full impartment of the subject.

With aids like these, it would seem that the art of ventilation could be brought intelligibly to the most moderate mechanical ingenuity, and that a few hours study would justify that self-reliance, which would prevent the professional man from giving place to merely artizan ability to repeat what has been done before, irrespective of differences of circumstances, and to protect the community against a presumptuous and bold empiricism, promising great results from insignificant means.

It may not be out of place to observe, that most of the examples which will be adduced as illustrations of the best results of modern ventilation, have been critically investigated by your speaker, during a recent short visit of exploration to the old world, devoted to this and some few other topics, connected with the completeness of our public institutions.

This declaration is advanced from no vain desire to give authority to opinions by any assumed weight of credibility as an eye witness, but from the notorious fact, that the accounts of most of these great works having been drawn up by their immediate friends, supposed inventors or suggesters, some safeguard seems proper against the undue partialities and extravagant eulogiums, natural enough to enthusiastic men, even when honest and disinterested.

It is worth while to mention in this connection, that almost all our accounts in the regular treatises, of improvements in heating and ventilation, are from writers, hardly standing in that disinterested position, which entire disconnection with the successful result of plans, would enable them to claim. The books on architecture, have hardly a page in a volume devoted to this subject. Some of the best known works make no reference to it whatever; and others merely sufficient to constitute an entry in the table of contents. A judicial mind thus becomes necessary, to separate the claims of interested partiality from the cool results of fact and experience.

The first illustration will be drawn from the recent arrangements under Dr. Reid's direction, for ventilating the English Houses of Parliament. This constitutes so marked and prominent an instance of the modern attempts in many of the works, that a brief history of still anterior trials on the same field may not be irrelevant. We can, in fact, upon this spot, trace the progress of the ventilating art almost from its first rude and undigested beginnings — at which I humbly conceive, we in this country now stand — up to that point of luxurious perfection, in which zephyrs, sifted and washed, cooled in icy passages in summer, and gently softened by the proximity of steam in winter, as well as impregnated with the balmy fragrance of "Araby the blest," are admitted in gentle and imperceptible volumes, — weighed and gauged, as it were, to fulfil the required demand.

From the varied ages and temperaments, the often impaired constitutions, the luxurious habits, the intellectual activity of so large and important a body, charged with so high functions, compelled to be together for many long hours at night, under circumstances often of the most intense attention and excitement, a defective ventilation must have been early recognized, and measures of relief projected. The illustrious Sir C. Wren, the original architect of the late edifice, as well as of all the best structures of the English metropolis, introduced nearly the same rudimentary method, so common with us, a specimen of which in fact ornaments, if it does not improve, this our anniversary assembly room. "At each corner of the house, in the ceiling, he made a large square hole, which was the bottom of a truncated pyramid, that was carried six or eight feet into the room above, and which was opened or shut with a kind of lid." "But it often happened," continued the describer of this early plan, "that when the pyramidal funnels were opened, the air above, being colder and denser than what was in the house, descended through the pyramids and annoyed the persons who sat beneath them;" one of the fatal objections to this plan which exists in undiminished intensity down to our days.

To obviate this difficulty the celebrated philosopher, Dr. Desaguliers, was called upon to devise a remedy. He constructed in the attic above the hall, a fire-place, the back and sides of which were of iron, forming a cavity, the upper part of which opened

freely into the atmosphere through the common chimney, while tubes from the truncated pyramids opened into the bottom of the box thus heated. * The obvious rarefaction produced an upward draught of vitiated air from the ceiling of the assembly-room. The activity of this current and the consequent change of foul air for fresh, would depend upon the amount of fire, and the freedom with which the replacing supplies were admitted below. From his description, it does not appear as if the Doctor appreciated fully the necessity of this last provision to a complete working of a ventilating plan. The effect of his arrangements, comprising so much of the true elements, as to render the remaining almost certain to be discovered on a fair trial, was defeated by the mischievous interference of an upper female domestic or house-keeper, who was deprived of some apartments by the occupancy of the space by the philosopher's apparatus.

In 1736, Dr. Desaguliers again introduced into the same edifice, the common centrifugal wheel or blowing fan, probably using it for the first time to propel fresh air into, or exhaust vitiated air from inhabited apartments. This machine for giving motion to air, is now in too common use in the arts of life to require a description. As a cheap and mechanical contrivance in winnowing grain, in furnishing liberal supplies of oxygen to facilitate the combustion

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* Fig. 2. Pl. I. *c*, *c*, are the pyramids, now closed at the top, opening over the hall and connected by the flues *e*, *e*, with the cavities x, x, of the enclosing iron box *a* : *b* is the fire grate, fed in the attic *r r*.

of anthracite and other fires in steam engines, in producing a copious evaporation where rapid desiccation is required, and other purposes in the arts, it is widely employed; its rotary motion being given by steam, water, horse, or human power. As the exterior of the case covering the wheel, or the opening at the centre, is connected with the apartment, so will be its effect in throwing in, or sucking out the contained air. The natural practical result of this property is, that to accomplish the first of these processes, the apparatus is placed below, in the cellar or basement; for the latter, in the attic, or above the apartment.

The Doctor's machine was driven by the power of a single laborer. The fan is described as being seven feet in diameter, and having twelve floats or leaves. The speed was doubtless as great as so limited a power could maintain.

This was the sole apparatus employed up to the year 1820, when an ingenious French nobleman, the Marquis de Chabannes, introduced his method, which had previously attracted considerable attention from its efficiency at the Theatre Royal, Covent Garden. It consisted, essentially, of a large trunk or chimney, opening at the centre of the ceiling, into which various smaller flues carried from the galleries, or other neighboring cavities, were admitted. A number of cylinders were placed high up in this main foul-air chimney, into which steam was admitted, from a boiler below or above, as might be convenient. The air, rarefied by contact and radiated heat from these cylinders, would ascend, and its place be immediately supplied from the vitiated air,

provided fresh supplies were properly admitted below; a point of great importance, now specially regarded, but, as before suggested, much overlooked in the earlier attempts.

The House of Lords, a much smaller apartment, does not appear to have been regularly ventilated, until within quite a late period. In 1811, Sir H. Davy was desired to furnish a plan, which duty he discharged. The following is an outline of his project. A grate or fire-place for the combustion of coals, was constructed in the attic, through the midst of which fire a tube of iron a foot in diameter was carried, so that the whole exterior of the cylinder was surrounded by the burning fuel. This cylinder was continued downward, in a copper tube of the same size, so as to open in the top of the ceiling, and upwards to the roof.* Sir H. Davy did not overlook the necessity of a free admission of air to replace that withdrawn, nor the importance of its not being admitted in unhealthy or unpleasant draughts or currents. This fresh air, whether warmed or of its natural temperature, was admitted through a multitude of perforations in the floor. Two lines of an epigram, written on the occasion, have brought down alike the evidence of this plan of diffused admission being no recent invention, as well as perpetuated the liberal reward he received for his scientific skill.

> "For boring twenty thousand holes,
> The Lords gave nothing——d—n their souls!"

* In Fig. 4, Plate I, *a* represents the escape flue with its lower end opening at the ceiling; *c* is the grate or stove enveloping the iron part of the tube.

This apparatus is said not to have been uniformly efficacious, although it is difficult to see wherein the principle of it was not sufficient. A writer suggests that the management of the windows and doors in the hands of careless or idle persons, explains the occasional reversed action which was complained of. The architect attempting to remedy this, removed the artificial heating above, and with it all the ventilation of the hall. Insufficient magnitude of apparatus was the probable explanation of Sir Humphrey's failure. Dr. Desaguliers' wheel had continued in use seventy-four years, proving a considerable degree of efficacy, at least, when the great fire occurred in 1834.

At this epoch, the construction of the new houses of Parliament was decided upon, on a scale of magnificence and cost, quite unequaled in the modern history of architecture. This is still in progress, not having received the finishing touches after a lapse of fourteen years. To render this national palace as complete in convenience, acoustic perfection, and healthful arrangement, as it is in architectural grandeur and artistic decorations, the scientific corps of the United Kingdom were invited to aid the Committee charged with its construction, in the various points of pure air, proper heating, and acoustic fitness. In the careful and minute reports of the evidence given by these men of science, we undoubtedly have all that was valuable, then known in the scientific world. The evidence of Dr. Reid, a lecturer on chemistry of some eminence at Edinburgh,

impressed the Parliamentary Committee so favorably on his examination, that he was instructed to enter upon an extensive course of experimental trials upon the edifice temporarily occupied for the House of Commons, in order that any important results might be transferred to, or incorporated with, the new edifice.

The building which has been the seat of Dr. Reid's labors, is, in fact, the old House of Lords, which was the only portion of the former structure preserved from the flames. His experimental trials have been diligently continued for a number of years, and in a field where no want of means is allowed.

Dr. Reid has been subjected to much ridicule and unkind aspersion, in regard to his ventilating arrangements; and a misunderstanding with Mr. Barry, the architect of the new Houses, has not unlikely prevented the full application of his entire views, in that location to which all his previous attempts have been preliminary. Although unable to perceive aught in the essential points of his arrangements, so novel or peculiar as to place Dr. Reid in the class of discoverers — nothing, perhaps, which was not obviously understood and applied under more restricted circumstances, by Desaguliers, Chabannes, Sutton, Hales, and Davy — yet it cannot be denied that in a full application of the principles of science in his preferred adaptation, he has done all which any man could do. If occasionally, under an embarrassment of riches, he has allowed himself to seek a degree of perfection, passing into over refine-

ment and fastidiousness, it is the pardonable error of aiming too high.

Under the obstacles which have prevented the completion of his great work, according to his views, it is probable we must be compelled to look at the present application, as the highest specimen of his success, — subject as it is, of course, to the difficulties of adapting new arrangements to an edifice long since finished.

A series of openings through the wall into a court yard, admits the fresh external air to the basement of the building. This being situated in a most impure and insalubrious district, it was necessary to connect the street sewers with the chimney, hereafter to be described, in order that their fœtid exhalations should not contaminate the air, at its point of admission. A suspended fibrous veil, 42 feet by 18, hangs before the external openings, the object of which is to separate the mechanical impurities, especially the flakes of soot, of which the London atmosphere is full, 200,000 visible portions having been arrested during a single evening.

The air thus screened, is next passed into a *receiving chamber*, constituting about one third of the basement. A partition divides this its whole length. At the middle of this wall, an opening permits the air to pass through an apparatus in which, by a thousand jets of water crossing each other in every direction, it is washed and moistened. It then passes amongst iron tubes filled with hot water, by which its temperature is raised to any required degree.

It now reaches a long chamber, parallel to the receiving chamber, from various parts of which, apertures are left which allow the air to press up into an *equalizing chamber* above, which extends under the whole hall of assembly. As the current passes up, it impinges against a flat board at each aperture, raised a short distance above, called a *disperser*, which throws the air somewhat horizontally, breaking its upward current.

No less than 300,000 of gimlet holes of a conical shape, with the smaller orifice upward, to prevent clogging by dirt, allow the air to escape into every part of the room above; and to make its diffusion more perfect, a hair-cloth carpet, woven porously for the purpose, gives it an extreme and universal separation.

At one part of the partition, between the first, or receiving chamber, and that from which the air is admitted after passing through the warming apparatus, is another door, making a direct passage for the fresh air without its impinging against the heater. By closing entirely or partially either of these two openings, as the case may require, any degree of change in heat can be obtained with but little delay. This circumstance, valuable in an edifice where the persons present may change from fifty to a thousand at once, or vice versa, is less imperious for common occasions, where no such contingency exists.

The escape of the vitiated air is provided for at the top of the room, where holes are left from one

end to the other into a horizontal channel above, which is received into a descending flue passing to the ground and communicating with the lower extremity of a brick chimney one hundred and ten feet in height. A fire-grate, with a door of supply for fuel, is placed in the centre of this shaft, a portion of the air passing under it to supply the combustion, and the larger remainder at the sides. A valve, or register, suspended in the main foul-air channel at the point above the ceiling where it turns to descend, regulates the rapidity of movement, and consequently, the quantity of air which is drawn through the house. In bringing the air downwards from the ceiling to the foot of the chimney, there is, of course, a loss of power in reversing the natural tendency of warm air to ascend. This, in an original construction, would be readily obviated by having the shaft commence in the attic. It still would be often a question, whether permanence of foundation and convenience of attendance, might not render practically eligible the additional height of chimney needful to counteract the loss by descent.*

* Fig. 8, Plate I, is a diagram illustrating the general outlines of Dr. Reid's celebrated attempt; *a* represents the place at which the outside air enters and passes in summer against ice suspended in a netting. In winter it is warmed by contact with the pipes represented in section *b*. Thence it follows through the passage *c*, and air chamber *d*. The current then ascends through the opening *e*, where its velocity is checked by striking against the flat board above. From the chamber below the floor, it enters through the gimlet holes and hair cloth, a portion being carried up by separate flues, *f*, to the galleries. Through orifices at *g*, it escapes into the foul-air chamber, *h*. From this, the suction of the chimney with the fire at its base draws down the foul air through the channel, *i*.

The house is heated to the temperature of 62° (F.) before it is opened, and maintained at a temperature between 63° and 70° by regulating the velocity of the draught.*

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* Any one desirous of verifying the remarkable uniformity in temperature maintained in the House of Commons under the peculiar difficulties, will find the tabular records of the thermometer in Dr. Wyman's Treatise, page 226.

Dr. Reid states, that after the completion of the alterations, and when four hundred of the Guards were seated, in order to make some acoustic trials, impossible with empty benches, the experiment was made of the power of the ventilating draught. Large trains of gunpowder mixed with oils and perfumes to increase the fumes and prevent detonation, were fired in the chambers below. The House was filled at once with so dense a smoke that few could see each other; but in a few minutes it was clear, the full power of the ventilation being put on.

Dr. Reid also states, that the greatest supplies of air are required in autumn, when the air is warm and moist, the wind imperceptible, and the barometer low. Fifty thousand cubic feet are scarcely then sufficient, per minute, to sustain comfort in a crowded house.

A very neat and satisfactory adaptation of Dr. Reid's plan of ventilation was described by Dr. E. Rigby, senior physician of the Lying-in Hospital in the York Road, Lambeth, a low section of the British Metropolis. The hospital was seldom free, for any length of time, from puerperal fever, occasionally producing frightful ravages, and requiring the building every now and then to be closed. "After the greatest attention had been paid to cleanliness in every respect, the wards left open night and day for weeks, fumigated, repaired, and frequently renewed, and the most scrupulous attention paid to cleanliness, the fever re-appeared, on some occasions, *immediately* on the hospital being opened."

Believing that the cause of disease existed in the malarious emanations of upwards of 1,500 feet of open ditches, the Commissioners of Sewers were induced to clean and arch over a considerable proportion, at a cost of £500, but without remedying the evil. It was then deemed advisable, in 1842, to adopt Dr. Reid's plan of ventilation; and accordingly, a large sum was expended in the necessary alterations. The annexed diagram, (Fig. 11, Plate II), will explain the general method. Fresh air was introduced under the roof, at *a*, in order to obtain a purer supply *at an elevation.* From a general air chamber, *b*, it descended to separate apartments; a hot water pipe, *c*, gave it a moderate warmth, double glass windows being also introduced. A vitiated air chamber, *d*, regulated by valves, received the air from the rooms. The air in the basement, contaminated by the proximity of drains and impurities below, was prevented from passing into the wards above by the flue *i*; the air from it, and from the chamber in the roof, passing down the shaft *f*, and then into the discharging chimney *g*, to which an upward current was obtained by the fire grate at its base; *i i* are registers commanding the inlet.

It may be well to mention, that the size of this room is 80 feet by 40, and 30 feet in height.

In consequence of jealousies and difficulties among the men of science connected with this immense undertaking, both painful and unnecessary to recapitulate, an entirely different and novel arrangement for the heating and ventilation has been provided, under the direction of Mr. Barry, the architect, and Mr. Bell, who seems to have devised the air and steam arrangements.

The air is received in the usual method into the basement, — is there compelled to pass through tubes which are enveloped in steam, and thus have the temperature of the passing current raised to the desired point. It then passes under flues beneath the floor, after the method used in heating the floors of the ancient Roman baths, which, through their cast iron coverings, part with a portion of their heat, and radiate it directly under foot to the room. It then ascends to a pure-air reservoir,

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After this plan was completed, much opposition to its fair effect was experienced from the female attendants, who closed the egress and ingress apertures. A recurrence of the disease was directly traced to this unpardonable interference. The drainage of the building was also found to be defective. After these difficulties were corrected, in February, 1843, to the time when the testimony was given, June, 1844, not a trace of puerperal fever had existed.

Dr. Rigby states, that before this plan was adopted, the air of the wards was always close, oppressive, and *bedroomy*, owing to a want of proper ventilation. But as soon as Dr. Reid's plan of ventilation was permitted to have a fair trial, the air became not only free from effluvia, "but has now a remarkably clean, clear, refreshing feel, which I can only compare to the sensation produced on entering an empty room which has been recently whitewashed." — *Health of Towns Commission, First Report.* Vol. I, p. 119.

which delivers it downwards from openings in the ceiling, through the carved open-work of the beams.

The foul air escapes into another receptacle above the ceiling, which communicates with a chimney or flue, into which a jet of steam is allowed to escape, producing a most effective draught.

In summer, the air is drawn in through the same orifices, the heating being omitted, and a channel is also provided, governed by doors, which allows as much cool air, for tempering, to enter, as the state of the interior may require. Indeed, it is proposed to fill the space ordinarily occupied by steam, with cold water, from an Artesian well, to reduce the temperature of the air as it passes. That the air is well diffused throughout the apartments is certain, from no draught being perceptible, as well as from the fact, that a hundred large wax candles are burning in the evenings unprotected by any glass, with perfectly steady flames, as well as from direct experiments like the following:

When the air in the supply chamber is fumigated with a perfume, the aromatic odor is perceptible in four or five minutes, by a person sitting in any part of the house, and in fifteen or sixteen minutes, all trace of the perfume has disappeared. The figures will explain the detail of this apparently very successful arrangement.*

* Fig. 21, Plate IV, represents a longitudinal section; A is the House of

Our next specimen of successful ventilation on a large scale, is the late Chamber of Peers of France.

The hall of assembly is in the Luxembourg Palace, situated in the centre of a large garden, and

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Lords. D the Victoria Hall or Lobby; E the Peers' Lobby; *a a a* the chambers under the house, &c. divided from it by a perforated iron floor, rendered air-tight from the house by a covering of lead. These chambers are for hot or cold air as may be required; C, the fresh air chambers in the roof; *c* the vitiated air chambers; and this part of the building is shown for clearness in double section; one half to represent the fresh air chamber, the other the foul or vitiated. The actual construction cannot be well shown in the longitudinal section, but is seen in the cross section where the centre division represents the foul-air channel, and the lateral spaces *b b*, are the fresh air receptacles. The dotted line *d d* indicates an iron tube for conveying the foul air from the Victoria Hall to the discharge shaft, wherein is the jet *f*, for moving the air; *e* is the foul air tube from the Peers' lobby to the same shaft; *g* the discharge shaft and chimney to the engine; *h* is the steam boiler; *i* the tubular arrangement by which the air is heated as it passes; *k* the orifice by which it passes into the diffusing chambers *a a; l* the steam pipe to supply the heater; *m* the room where the temperature is regulated; *n* the flues of the south wall of the Victoria Hall, up which the air passes with great velocity to the supply chambers, over the ceiling, two flues being appropriated to the Victoria Hall and four to the House of Lords; *o* continuation of flue for air from basement. Each flue has an area of six feet, thereby allowing the passage, with the ordinary velocity, of upwards of 7,000 cubic feet of air per minute; *p p* passages to supply the heater; *r* doors to shut off hot air.

Fig. 20, Plate IV. is a transverse section of the same; A House of Lords; B B the lower corridors; C C the upper do.; *a a a* the air chambers under the House; *b b* the fresh air chambers over the ceiling; *e* the foul-air chamber; *d* foul-air tube from the Victoria Hall. The flues on each side, from the air chamber *b b*, downwards, convey the air, if required, to the underside of the covings to the galleries, through the ornamental work. The air enters from the river side, the edifice being on the margin of the Thames, through a passage into a small chamber, on the floor of which are five or six inches of water, and passes through a finely perforated zinc screen, over which water is constantly trickling, and is thus freed from impurities. It then passes through the pipes, surrounded by steam, and thence to the chamber beneath the house; nearly 40,000 cubic feet being thus always ready for admission. The air next passes up the flues in the wall of the Victoria Lobby, into the upper reservoir over the ceiling.

The vitiated air is drawn up from the body of the house through the perforated enrichments in the beams of the central division.

The currents from the supply chambers are poured down through multitudinous perforations, in the side divisions, the two currents meeting in the centre of the chamber. The foul-air shaft and the chimney are united above.

under favorable circumstances for a pure circumambient atmosphere. It is a semi-circular apartment of about sixty-five feet diameter, with galleries for the spectators on the sides. The air for warming and ventilation is brought from the open garden in an underground shaft of masonry, about ten feet square. At about the point where this airduct enters the cellar, two fan wheels are arranged, each two metres, (between six and seven feet,) in diameter, and one and a half metre, (about five feet,) in length, and each with six floats or leaves. These are propelled by the labor of two men at a crank, banded to each wheel, and geared, to provide a suitable speed for such a motive power. These draw in the air from the outside, and at the same time drive it forward, and amongst the hot water heating pipes. It pursues its course thence by various upright flues to the apartment where it is to be used, and which it enters through a vast number of small orifices, dispersed in the risers of steps, and other convenient points, so as to produce a proper extent of diffusion. The vitiated air escapes at a large circular opening in the centre of the ceiling, directly under which hangs an immense chandelier, the heat from the numerous gas burners of which, occasions a powerful rarefaction, and consequent upward ascent of the air. The galleries are connected with the main trunk, by collateral flues entering it.

It was determined by various experiments, conducted with that system, science, and deliberation, for which the French philosophers are so distin-

guished, that this apparatus in its usual full action, withdrew each hour 425,700 cubic feet of air.

The summer ventilation was effected by adding the action of another pair of centrifugal fan-wheels, of the same dimensions, and propelled in the same manner, to supply the upward force of the heating apparatus, the use of which being, of course, then suspended. Moved at their ordinary speed, it was found that seven cubic feet of fresh air were supplied each minute, to each person.

The sufficiency of these arrangements, designed by M. Talabot in 1840, were tested and approved by a government commission, consisting of M. M. Thenard, Gay-Lussac, Poullet, and Péclet, some of whom have a world-wide reputation in science.

Let us pass to another class of institutions — from palaces to prisons. The condition of these was most early and prominently connected with the history of ventilation, as well as of epidemic disease. The writings of Howard, the history of the Black Assizes at Oxford, and other sad memorials of the fatal ills resulting from prison-air, attest how fully the necessity of artificial changes of atmosphere was required, long before science had lent its aid. And in these very seats once of the most pestilential miasmata, we now find the most complete and luxurious examples of the application of our art.

The Model Prison, as it is termed, at the suburb of Pentonville, near London, was in every particular designed by the most competent persons, with the most unrestricted provision of means, to fulfill the

highest attainable perfection in all its material arrangements, especially in its heating and ventilating. Although some respectable observers have supposed that they had detected deficiencies in the operation of its apparatus, yet it is certain from the Parliamentary Reports containing the exact tables of Dr. Rees, the physician, and others, — presumptively incapable of bending, much less of falsifying records of numerical facts, — that the quantity, temperature, and hygrometric condition of the air, furnished to each convict, are measured with almost as much certainty and precision, as his food, drink, or light. The form of prison discipline there adopted, would be considered with us a mild and modified form of the Philadelphia or separate system. Each prisoner is detained constantly in his cell, except during a comparatively liberal allowance of time devoted to religious exercises, educational improvement, and out-of-door exercises. Each cell is thirteen feet long, seven feet wide, and nine feet high, to the key-stone of the arched ceiling above, and consequently contains about 820 cubic feet of space. It is, however, scarcely worth while to adduce a point so immaterial in any true system of ventilation, as the size of an apartment. The windows are stationary, and each cell is fitted up with water-closet, washing apparatus, gas burner, besides bed, table, and seat, together with the loom or other implement of the mechanical art, pursued by the inmate.*

* Fig. 10, Plate II, is a diagram reduced from one of the elaborate and exact

An under-ground flue, commencing at a low tower to protect the inlet from animals or other accidental sources of impurity, brings the pure fresh air into contact with the hot-water circulating apparatus in the basement of the building. This apparatus consists of plates and tubes of iron, filled with hot water, which dispenses its heat, by conduction and radiation to the air, as it passes by to enter a flue or channel running from the centre to the ends of each corridor, just in front of the ranges of cells. From this horizontal channel, upright flues are carried into each of the two stories of cells, and are made to discharge themselves near the ceiling, and are controlled by registers, to regulate the admission of warm air.

The foul-air or escape flues open in a grated orifice, about two feet long by six inches wide, near the floor, and thence pass up in flues in the wall, into the attic, where they enter a common horizontal channel, the end of which terminates in the large chimney shaft, rising twenty or thirty feet above the ridge of the roof.

The smoke flue of the fire which heats the water for warming the air, opens directly into the foul-air chimney, and, by the rarefaction produced, consti-

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drawings to a scale, published in one of the Reports to Parliament — to which reference is made, for any desiring more precise information of the architectural detail. The cold-air flues deliver the fresh air under the hot water apparatus at C. It passes up the flues EE, to the top of the cells GG. The foul air leaves the cell floors at FFFF, ascends to the attic channel H, where the smoke flue is turned in, on one side. For summer service, a grate and fire at I, aids the ascent into the flues KK, which become one by the partition or withe at L, having been omitted.

tutes, in the winter season, the motive or exhaustive power, — the warmed air also aiding to some degree the egress of the vitiated air, as it enters the cells, by its *vis a tergo.*

In summer, when it is desired that the air should enter through the same channels, but without heat, a fire is made in a grate inserted in the chimney, and accessible from the attic, through and by the sides of which the foul air ascends and escapes. The peculiar advantage of having the warm air admitted at the ceiling, is, that the change of direction diffuses it through every part of the cell, breaking up the draught; and it is also less likely to be interfered with, polluted, or blocked up, than if admitted at the floor. The effluvium from tobacco or other impure ejections, instead of combining with the entering current, to be imbibed in respiration, is drawn out forthwith — a circumstance of unusual importance in all American attempts at ventilation, where the personal habits of the community, in some respects, are so exceptionable. The only objection to this reversed movement of the current, is the loss of ascensive force, easily supplied by a little addition to the fire.

The whole arrangements of the Pentonville prison, relating to ventilation, contain so complete an embodiment of one of the most common of the modern systems, as to be worth a closer investigation than the discursive character of an address will permit. A reference to the accompanying plan, will enable its action and its efficiency to be fully comprehended.

In the continued advances made in a country of so much capital and science as Great Britain, we find the same general system introduced, in later constructions, with improvements in those particulars where experience had shown defects.

In the immense penitentiary, established at Wakefield, in the West Riding of Yorkshire, the hot water pipes pass along a channel, or large flue, which runs from the central boiler to each end of this corridor. Each section or joint of this iron pipe is increased in diameter in order to compensate in quantity of warming fluid, and extent of radiating surface, for the diminished heat lost in passing from the boiler. In this institution, the foul-air flue, instead of opening at the floor and then passing upward, descends from the lower part of the cell, and enters a horizontal drain, the common receptacle of all the foul air flues, which delivers its contents into the upright chimney shaft, partly entering through, and partly around the fire-grate, as usual.

Few classes of inhabited buildings demand so effective, certain, and controlable means of supplying pure, and removing vitiated air, as hospitals for medical and surgical diseases, and asylums for the insane. In these, pure air becomes not merely hygienic, but sanatory — not only a preservative, but a curative appliance. As respects the first-named institutions, their history in all countries demonstrates not only how important ventilation is as regards those forms of epidemic and contagious diseases, directly resulting from impure air, as typhus, erysipelas, hospital

gangrene, and the like, but as respects those general results of aggregate experience for years, not less certain, although less palpable. The statistical results of simple amputations, in particular hospitals of Paris, and in the whole, are well known to those interested in surgery, and most strikingly illustrate the connection referred to. In the latter class, those for the insane, the peculiar depressive, torpifying influences upon the mind and feelings — the intellectual and sensitive faculties, are now universally acknowledged, and are as susceptible of proof, as any of the purely physical disorders, dependent on vitiated air. I have frequently thought and observed, in passing from one to another of the lunatic receptacles of the old world, that a glance upon the countenances of a group of the inmates, would at once tell the fact, whether they habitually dwelt in a habitation, the purification of which was abandoned to the chance changes from doors and windows, and the almost equally unreliable draughts of upright flues, in which the currents of air were spontaneously determined only by the accidental preponderances of internal heat and external currents; or whether they passed their days and nights in that pure, elastic, healthful medium of equalized temperature, qualified hygrometric condition and copious supply, which some of the modern and improved exhaustive arrangements so fully command.

The eminent philanthropist, Dr. Southwood Smith, in his testimony before the Parliamentary Commission, is the first writer who appears to have recog-

nized fully the connection between the intellectual and moral faculties, and the habitual imbibition of vitiated air. "The poison," he observes, "generated in these neglected districts, and to which these persons are habitually exposed, is a sedative poison, among the most distinctive characters of which are the depressing effects produced by it, both on mind and body. This is one of the main causes, not only of the mental apathy, of which I have already spoken, but also of that physical listlessness which makes them incapable of any great exertion. I am satisfied that this feeling of depression, is one of the chief inducements to the use of stimulants."

Let us select an example of improved insane hospital ventilation, which has undergone the test of a dozen or fifteen years' actual and successful experience, in the asylum of the county of Kent, at Maidstone, in the southeast part of England. This was arranged for a complete exhaustive ventilation from its commencement, under the direction of Mr. John Sylvester, who has long maintained an eminent place in this department of applied science, and the basis of whose arrangement is that originally suggested by Mr. Strutt, of Derby. I prefer giving the substance of his own account of what it is, with suggestions as to certain alterations which he would subsequently have recommended, as inferred from his testimony before the Parliamentary Commission so often referred to, in preference to using my own notes of a visit to, and examination of, the institution itself. I need only say as regards the example

itself, as I found it, that nothing more satisfactory could be conceived. The distinguishing peculiarity is the supply of the whole edifice with an immense volume of air, warmed scarcely above the temperature at which the interior was designed to be maintained. This system is predicated on the principle, that in certain circumstances the unpleasant exhalations from the diseased human body require a change of air, far greater than the quantity indicated for the vitiation produced by the respiration processes. The pure air is received by means of a large revolving cap or cowl, kept with its open side to the wind by a vane, into a tower of moderate elevation, a few hundred feet from the buildings, to prevent any obstruction of wind, or defilement. An underground channel of masonry, two hundred yards long, and six feet square, terminates at the usual hot water apparatus, with the exterior of which the passing current is brought in contact, and thus ascends in immense flues, which open near the ceiling of the galleries. These channels are all so large as to allow the velocity of the air to be exceedingly small, moving through the underground channel only at the rate of four feet per second. The air, at its point of delivery, by its amount, its gentle current, and its moderate temperature, reminds one of the gentle, elastic breeze of the tropics; and there is in its large volume and slow movement, little necessity of any arrangements for divided admission, or other diffusive means, to enable a general and uniform spreading of it to be attained. An exhaustive apparatus

of the simplest kind and least force is sufficient to deflect and scatter a current moving at this slow rate. Mr. Sylvester thinks that it is desirable that the rate at which the air should flow into the interior, should not exceed half a foot per second, or about a third of a mile an hour.

Mr. Sylvester's plan provides ranges of pipes, filled with steam, in the attic, to raise the temperature, and by rarefaction produce the upward current. The summer ventilation is through the same channels, omitting the warming as the air enters. A vacuum cap, turning its mouth to leeward, permits the vitiated current to escape, and when the air externally is in motion, is of some auxiliary service in this way.

Mr. Sylvester, in explaining the plan he would adopt for ventilating the House of Commons, estimates the entire interior contents at 200,000 cubic feet; and here he purposed admitting the air over the whole area of floor, as far as practicable. The combined area of the apertures to this end he calculated at 665 feet. The current of air was to flow in at the rate of half a foot per second, at which velocity it would change the contained air six times within each hour. He would admit the warmed air at a temperature within 5° of that at which it was decided to maintain the house.

The diagram and explanation will give a clear view of his ideas of ventilation, in the experience of which, in the largest and most complete examples in Great Britain, he seems to have had far

more general opportunities than any other individual.*

In another example of a lunatic hospital, the most modern and complete of the French institutions, the Maison Royale, at Charenton, the exhaustive power to withdraw the vitiated air is formed by running the small pipes filled with heated water longitudinally through the foul-air flues; the rarefaction thus produced liberates the foul air, and draws in the pure supplies below.

I will adduce from the elaborate and scientific work of M. Péclet, a still further illustration of a plan of ventilation, which has stood the test of experience, in a hospital for common diseases, referring to the drawing for the exact details.†

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* Fig. 9, Pl. II. is reduced from the plan offered by Mr. Sylvester to the Parliamentary House Commission; *m*, is the body of the house; *a*, is the tower, which admits the cold air and allows it to pass through the channel *h*, impinge against the hot water or steam pipes at *c*, and then is admitted through the floor *d*, as the arrows indicate; *i*, *i*, are the escape holes in the ceiling; *n*, the steam pipes which serve as the motive power; *o*, is the turn-cap, moved by the vane so as to present its mouth to the leeward; *x*, is a flue which would allow the warm air, by means of a register, to pass directly into the attic, aiding the upward ascent, and acting as a waste when too great heat arose from the apparatus; the aperture, also marked *x*, near the floor, enables the foul air to be drawn off at bottom, when the upward orifices are closed by their registers.

† Figs. 15 and 17, Pl. III. represent the middle section of a hospital of three stories. In the cellar is the air-chamber, containing the hot water apparatus, and channels communicating with the external air. A, is the boiler; E, a double spiral coil of iron pipe, to give ascent and some warmth to the air of ventilation, which then ascends in the flue F, which distributes it on each story. It passes along the corner of the walls, at G G, H H. The foul air escapes into the attic, from which it escapes by the chimney I, aided by a grate for summer use. The hot water is carried into each story and radiated from the hot water stoves, D, D, D, &c. Fig. 17, is a ground plan of a part of one of the stories, showing sections of the ventilating flues H, H, H, and the horizontal branches *g*, *g*, *g*, opening under the beds.

In the middle of the cellar is a large air chamber, receiving its fresh supplies from the outside. A boiler of water having a concave bottom to receive the full force of the fire, is placed within the air cell, from which radiate the tubes designed to warm the house. One of these tubes proceeds from the bottom of this boiler, passes to the lower end of a fresh-air flue, which leads from the air chamber communicating with the exterior, and is then twisted into a double spiral nearly filling the width of the flue. A certain degree of ascensive force is thus given to the air of ventilation. This air channel sends off branches as it reaches the different stories, in wooden boxes which deliver the fresh supplies at various openings. A horizontal branch passes out under each bed, where it delivers its pure air, slightly raised in temperature, through three free openings, a valuable point of the operation of which is understood to be, that a sheet or curtain of pure air, rising around the patient on every side, protects him against the approach of odors or exhalations from those in adjacent beds, as it does them from his.

The vitiated air is conducted through a set of escape-flues, which terminate in the attic. A chimney proceeds from the attic upwards, a fire-grate at the inferior orifice of which gives activity to its draught. The interior is heated, in addition to the small amount of heat contained in the air warmed for ventilating purposes, by one of the varieties of the mild

hot water apparatus*; the tubes from the boiler in the cellar, passing to what are termed hot-water stoves, which are merely ornamental iron reservoirs of hot water, having a pipe for its admission and return, and the large radiating surface of which raises the interior atmosphere to the requisite temperature. The peculiarity of this arrangement is, that the heating and ventilation are combined in a certain way calculated to save any waste which would occur from heating more of the external air than is necessary for the due restoration of the atmosphere.

An example of the every-day application of some of the true principles of heating and ventilation in a cheap and simple form, will be found in a common Parisian school-house. The specific example is taken, with the annexed sketch,† from the work of Péclet, although the general principle has long been in common use, under very many modifications. The apartment is of a rectangular form, and about of the dimensions of one of our larger forms of grammar school-houses. The teacher's desk is placed within a few feet of one end, and in the middle. On each side of this, and midway between the

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* Those forms of hot water apparatus, in which the fluid is raised to a temperature not exceeding 212° F. are designated under the term *mild*, in contradistinction to Perkins's intensely heated water tubes.

† Fig. 13, Pl. III, is a diagram of a room of the school-house, shortened in length for convenience. B, B, are the seats; C, the stove covered by its case; D, is the funnel entering the chimney, E; *i*, is the damper in the cold-air flue; *f*, is a grate inserted in the chimney. Fig. 14, is an end view to show the mode in which the foul-air flues enter the chimney; *b*, is the door to the ventilating grate; F, F, revolving registers; E, the chimney.

sides of the house, are placed two coal stoves, very similar to the common cylindrical anthracite stoves, in so common use among us. This is covered over with a case of iron, copper, or other metal, leaving a space of three to six inches between. The case extends to the level of the floor, where it rests upon a groove in a cast iron plate, which is set over a flue extending horizontally under the floor to the external air. Various holes are left in this plate, so as to allow the fresh air to pass up in the interspace between the stove and the exterior case. It is warmed by this contact, and escapes freely either by large openings, or small perforations around a few inches of the top of the case. The top is usually flat; and the impulse of the air, striking against it as it rises, naturally diffuses and spreads it much better than if the apertures of exit were more direct in the top itself; the lower surface of this cover has been made in the form of a blunt cone, or segment of a sphere, to produce this effect more freely. A valve or damper in the cold-air flue, commanded by a handle, permits the amount of air admitted to be controlled.

The funnel is carried in the usual way, perpendicularly, high enough to prevent any undesired radiation upon the heads of those seated beneath, and then horizontally to the middle of the opposite end of the school-room. Here it enters a smoke chimney which commences at the ground level. At three or four feet from the floor are openings, commanded by revolving registers or other valvular

arrangements, which admit the foul air into the chimney by the suction produced by the rarefaction resulting from the stove pipe which enters above. At the same level, or a little above, a fire grate is inserted in the chimney, with a door for feeding. This of course is designed for the summer ventilation only, when the heating fire is omitted; and the pure air supplies are drawn from the outside through the winter channels, with perhaps additional and more direct orifices of admission, but without opening the windows.

I am aware that this form of air stove or furnace has been pretty widely used in this neighborhood for a good many years; but the long previous experience in France is corroborative of its excellence. It has been a common mode to place anthracite stoves in the basement vestries of churches, with an air flue running from between the coal vessel and the external case, often of tinned iron, kept bright to prevent radiation at a point where it is undesirable. The hot-air flue is carried directly into the church or hall above. An opening is also left in the external case in the vestry or basement below; and the dampers commanding these respective places of exit of warmed air are connected by a wire, so that when one is opened, the other is necessarily closed. A damper in the external air-duct should never be omitted, as otherwise the varying direction and strength of the winds will produce an irregularity in the supply. If the cold-air duct can also be extended out to the open air on both sides,

a great improvement in its regulation will result. The connection of the dampers admitting air into the respective rooms where it is to be used, is quite indispensable to obviate the danger from careless or ignorant persons closing both at once, an accident which terminates in a destructive accumulation of heat, pernicious to the purity of the atmosphere, and melting and warping the tin coverings, and even the fire surfaces.

The plan of heating, and consequent partial provision for ventilation, recently recommended and introduced into some of the Boston school-houses, is, essentially, that described above. A stove is used in its position, construction, and receipt of fresh air, precisely similar to those long employed in France and elsewhere, except that the warmed air, instead of being allowed to escape through large openings, or small perforations around the top, passes directly out at the upper point of the interspace between the case and the stove; while an obtuse, conical top with its hollow downward is suspended, or slips on a rod or on the funnel of the stove, as if designed to act as a register, which has received the name of a *distributor*. If this is allowed to be closed down to a certain point only, wide enough to give full egress to the warm air, it does not differ much from the common French cover, in which the oval openings are large, and separated by columns or wires of metal sufficient to give firmness to the top. If it is allowed to slip down, so as to act as a valve, and interfere with or prevent the escape of heated

air, the apparatus is brought back at once to a species of old box stove with double walls. The attempt to regulate the quantity of heat admitted to a room in any form of calorifer or hot-air furnace, should be made any where else rather than at its point of escape. The heat is only accumulated by such attempts to be expended upon the stove itself, and then to *roast* the air. Indeed, with a command over the admission of the air of combustion, over the register of the ingress flue, and for extraordinary emergencies, with a waste opening to the outside from the air chamber itself, no necessity need exist for checking the heated air at its outlet.

The Boston school-houses appear to have their exhaustive power furnished in a much less reliable method than in our French specimen, that is, by a chimney cap. The attempt to obtain an upward current, by the action of the wind upon any form of cap, is for obvious reasons perfectly inadmissible in any true ventilation. That employed in the instance adduced, was invented by St. Martin, in 1788; and, when made at a proper angle — which is found by Dr. Wyman's investigation, to differ some degrees from that most frequently used by our manufacturers — is as effective, perhaps, as any apparatus of this kind when the wind blows.*

The absence of any apparatus for fire at the foot, or any other point of the foul air or smoke chimneys, would seem to imply that the summer ventila-

* See Report to American Academy of Arts and Sciences, on Ventilators and Chimney Tops, p. 14.

tion is to be principally dependent on the opening of windows. This, it is hardly necessary to say, must be considered as a great defect in any complete modern ventilation for school-houses in large and noisy cities and populous towns.

A form of this, which is in fact a kind of air furnace in the room itself, much used in some parts of Europe, is selected from among a great variety given by Péclet, and a copy of it annexed will explain itself at a glance.* The cylinder stove is covered with a case of metal, crockery, or even stone, more or less ornamental, receiving its air from the outside, warming it as it passes the interspace, and delivering it around the upper few inches of the top. The funnel is carried directly through the fire-board or masonry filling the original fire-place. Here also is inserted a revolving register, or other movable valve. The heat of the smoke produces a lively upward current. This sucks off the lower stratum of air of the room, draws down the warm portions, and thus equalizes the temperature throughout, while it is renovating the whole by degrees.

Three registers, one in the cold-air flue, one in the exit or foul-air flue, and one in the smoke-flue to command the rapidity of combustion, enable the management of it to be controlled with the smallest amount of intelligence and observation.

* Fig. 16, Plate III. In these two examples, the air stove stands before the closed fire place; A admits cold air from without, into the interspace; B is the smoke-flue; C the foul-air duct.

After all, however, these are merely forms of hot-air furnaces placed in the apartments, instead of the basement or cellar beneath; and it is questionable whether the comparison of conveniences and disadvantages will often justify this location. The fact that in all combustion of fuel, especially of the carbonaceous varieties, there will be some escape of ashes, or of gases, into the room where it is used; the inconvenience of feeding the grate in the room itself; the care of preserving an exterior of metal in a clean condition; the greater inconvenience of establishing an evaporation of water into the air heated, and some other objections, may sometimes be overbalanced by convenience of attendance. Usually, however, in public buildings where the extent of operations will justify the attention of some person to the business of heating and ventilating, the true point of location for the hot-air apparatus is in the cellar or basement.

The character of any variety of the hot-air furnace is measured, in my judgment, by the simplicity of its construction, its non-liability to be brought to an undue degree of heat in any part, and its ready receipt and emission of air. That made and sold by Mr. Gardner Chilson, of Boston, with an air chamber of brick and an interspace of two or three feet in width, appears to me to combine all the essentials attainable of this mode of heating air more fully than any other which has fallen under my observation. In proportion as they approach the old Wakefield furnace,—in which the

sides of the air chamber are removed from the *cockle* or fire-vessel by an interspace of a few inches only, and the passing air is held in contact with the overheated surface as long as practicable by various turns of direction at right angles or those forms of the French calorifer, in which the cast iron tubes are heated to a red heat, while the air to be respired is passing through them,—so far do all the various hot-air furnaces deteriorate in healthfulness and comfort.

A single other illustration of successfully arranged ventilation on a scale and after an experience sufficient to give it a character, will close this part of our subject, and enable us to pass to the generalization deducible from the mass of individual instances, each one of which is of course merely a type of more or less numbers. The National Bank of England and also of Ireland, have been ventilated under the direction of the bank engineer Mr. Oldham, by the revival of a method,—the employment of bellows, or the blowing cylinder, introduced more than a century since (1741), by Dr. Hales, into many of the prisons, hospitals, and other buildings of the British metropolis, and into nearly all the ships of the Royal Navy, and in many instances, when under adequate supervision, with the greatest success. At that period when steam power was unheard of, instead of being as it has almost become in our days an appliance of domestic use, the apparatus was dependent on human labor,

which must have rendered its employment inconvenient and uncertain.

Mr. Oldham availed himself of the steam engine in use for printing and other processes of the establishment, to give motion to a large blowing cylinder of the double-acting kind, drawing its supplies from the outside, and forcing the air amongst the steam heating tubes, until it enters by many orifices the large room in which the many officers and persons having business are congregated. The temperature is of course easily regulated by the extent of radiating surfaces employed and the activity of the air-propelling movement.

Having now recapitulated in a brief manner, but still, it is hoped, with all the characteristic and distinguishing features, the principal examples on a large scale of modern ventilation, it remains for us to attempt to generalize the various points and peculiarities, to select the essential from the accidental, and deduce principles of universal application from instances in which they may be more or less distinctly combined.

The first peculiarity which strikes us, is of a negative character — the omission of all reliance on, or provision for the admission of the pure element, or the discharge of it when vitiated, through direct lateral openings, doors, or windows, — methods so primitive and so universal, that at first glance we almost deem them the natural modes. In fact, these ready substitutes have been proved by all experience to be wholly

unequal to the duty; and also so incompatible with the systems involving other indispensable points, as to render their entire omission a first principle. Every modern system, as shown in our illustrations, recognizes the closure of all orifices not connected with, and forming part of the ventilating system, as a matter of course; the windows in fact, generally being made double, either by duplicating the sash, or what is better, having a second range of lights set in the same fixed sash, with a confined stratum of air between half an inch thick. The doors also are duplicated at the extremities of a short passage or entry, so that the one in front is not opened until that in rear has thrown itself to. In fact, the cross-draughts, supplies from sources and emissions of air at points not determined by the motive power, would be utterly inconsistent with any uniformly arranged plan. As Dr. Reid well remarks, in any scientific plan, the apartment to be ventilated is to be deemed and treated as a piece of philosophical apparatus, the results of the operations of which are to be interfered with by no fortuitous influences.

The second point of agreement in our examples is also of the negative or omissive character. This is the abandonment of all attempts to rely upon the slight differences of temperature and the resulting ascensive power, derived from the presence of numbers of occupants, or from the ordinary artificial warming. Though under certain favorable circumstances of aerial currents, external and internal states of the thermometer or other contingencies, flues for

permitting vitiated air to escape and its place to be supplied by fresh quantities, may operate with some energy, yet experience shows that it is a system too capricious, too wholly devoid of that certainty and controllability, radically essential to a perfect ventilation, to be thought of at this day. This is the mode which has obtained so generally in our American prisons, hospitals, and public assembly rooms, and from its unfortunate universality its consideration deserves more detail than the present limits permit. In the Appendix, a practical view of the circumstances affecting the delivery of air through various forms and conditions of flues will be given.*

The third circumstance of uniformity in our successful examples adduced, as well as in a wider spread series of cases, (were it of moment to investigate them,) is also one of absence: viz., the omission of dependence upon all kinds of apparatus or contrivances operated upon by the passing current of external wind. This, of course, comprehends all kinds of turncaps, cowls, louvres, and the like. In some instances, the *plenum* and *vacuum* cowls, as they are respectively termed when their open mouths are turned to or from the wind, giving them a filling or exhausting action, are advantageously employed as a collateral or auxiliary measure, saving a certain amount of motive power when in action, but never trusted to as the effective and constant power.

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* Appendix A.

With respect to all the hundred varieties of contrivances of the turn-cap or cowl order, most of which have been invented and reinvented every few years, their whole consideration may be briefly despatched in simply observing that their utility is wholly dependent on a movement which frequently, at uncertain times and sometimes for long intervals, ceases to exist. Consequently the ventilation of buildings depending on the winds, must be just as uncertain as the wind itself, and the occupants of a crowded habitation might as reasonably trust to the prevalence of calms and breezes in a certain sequence for their food and drink, as for their air.

During brisk and active winds, any varieties of them will produce a considerable fluctuating, upward draught. At such times, however, the natural ingress and escape of fresh air unassisted, is the most ready, and of course the necessity of artificial aids the least urgent. In the stagnant, heavy atmosphere, prevailing not unfrequently week after week at certain seasons of our climate, the necessity of certainty of change becomes the most imperious. The effect, at these important times, of any or all of these multiform contrivances is only that of impeding whatever disposition the internal air has to escape arising from augmented temperature, by more or less obstruction at the orifice of the tube, amounting in the least unfavorable specimens of the revolving kind, to one turn at right angles and the friction of more or less uneven surfaces.

The experiment of two distinguished practical mechanics in New York, Messrs. Ewbank and Mott,

demonstrated that there is a considerable difference in the exhaustion of these variously shaped contrivances; that is, when they do act at all. The exact, certain, elaborate experiments on certain varieties of these things, made by a committee of the American Academy of Arts and Sciences before referred to, the detail of which was directed by Dr. Wyman, forever settle all controversy as to the respective merits of the different specimens tested, as well as the want of originality in any modern modifications.

In reverting to the points of positive accord in our examples, we find that they all present a common feature in the following essentials.

I. The obtaining the fresh air from pure external sources, by distinct, appropriate, ample avenues. It is never taken from the cellar or basement of the building, nor from the accidental crevices, or passages provided for other uses. Most frequently a channel of masonry is constructed under ground, and carried to such a distance from the house as to make sure of a pure admission. A tower, or chest with openings, prevents the orifice being blocked by snow, or the accidental admission of living animals or other impurities. Local sources of impure air, which cannot be better avoided by the selection of a spot for the outer opening, are connected with the exhaustive arrangements. Sewers which may be crossed, are covered with air-tight cement work. In fact, no pains are spared to obtain the air in a perfectly pure condition.

In cities where carbonaceous flakes are common,

a fine wire netting is thrown across the flue to arrest the palpable defilements. Even veils of fine gauze cloth are used by Dr. Reid, and the finest perforated sheets of zinc by Mr. Bell, to stop the impalpable, dust-like particles; and the air is also washed by jets of water, crossing each other in every direction, or by water dribbling over the perforations.

Mr. Sylvester found in his trials, that there was still another advantage in bringing the air through long underground channels. They had the effect to equalize its temperature. In one hundred yards, for instance, it received in winter about 15° of heat, and lost the same amount in summer. In the intense heat of our northern summers, this last advantage, combined with the hygrometric addition of jets of water, would be no small consideration.

In Dr. Reid's plans for the new parliamentary edifice, he proposed taking his fresh air at the top of a tower some two hundred feet from the ground, from the difficulty of finding a pure source at the level, in the impure and crowded district in which it happens to be located. This arrangement of course is attended with the sacrifice of motive power necessary to reverse the admitted column of air.

In various foreign instances, of which one example is presented in Dr. Rigby's evidence,* the air is admitted under the roof, and carried directly downwards to pass through the heating apparatus, from

* Fig. 11, Pl. II, described in note, page 46.

which it is then delivered into the rooms above. The air describes three sides of a square in its course.

In various instances, to prevent the irregular draughts through the ingress channels, the air is received into a chamber of considerable size, which acts as a reservoir, destroying the motion of the air. It is then subject to the equable indraught of the motive power. Our examples refer to the placing of ice suspended in a netting, to reduce the temperature in the heats of summer, or filling the steam or hot water heaters with cold water in circulation for the same end.

II. Raising the air admitted to produce warming and ventilating, only to a very moderate temperature.

The subjects of heating and ventilating are so intimately connected in practice, that they can hardly be treated of separately. In our examples, the summer ventilation is often carried on by an arrangement independent of the heating. In winter, the two processes appear to be rarely entirely disjoined.

It seems to be admitted universally, that the true principle of heating the air is never to have its temperature raised above what results from the contact and radiation of metallic plates or pipes, filled with hot water or steam. A peculiarly unhealthful change appears to be occasioned by raising air, even apparently free from appreciable accidental impurities, to any higher heat than about the boiling point.

Whatever may be the chemical changes in air so heated or the pathological effects of its respiration, the actual annoyance arising from *roasted* or *scorched* air is too notorious to be doubted. Its probable explanation is the decomposition of floating, impalpable particles of vegetable and animal nature — certainly not, as is often suggested, and even provided for by stone or earthen radiating surfaces, any deoxygenation from the combination with the iron, since this is chemically impossible, and equally observable when no oxide is formed.

So impressed was that eminently practical philosopher Mr. Tredgold, with the exceptionable character of any air introduced heated above the temperature of boiling water, that he declined taking into view any of the varieties of apparatus in which such a result is practicable. All kinds of stove heat he regards as wholly inadmissible.

It is probable that some few of the hot air furnaces composed of a very extended dome or *cockle*, air chambers sufficiently large and arranged for so low a temperature as to allow a person to enter and remain, and with perfectly free avenues of admission and egress of air, may not fall within the purview of his unrestricted and generally correct dismissal of this class of apparatus.

Public experience has settled down into the conviction that this moderate elevation of temperature can be best secured by the use of steam, or the mild hot water apparatus. This latter name is, as before intimated, applied in contra-distinction to the system

of hot water pipes invented by our countryman Jacob Perkins, a few years since, in which water was heated in small strong pipes to a temperature of several hundred degrees, and radiated heat proportionably. The facts that the air was vitiated by these, as much as if heated by blazing fuel inside, and that the apparatus was complicated and hazardous, have occasioned so general an abandonment of his method, as to require for it merely a simple recognition of its existence. It certainly ought never to be used where the highest perfection is sought.

The heating apparatus, whether hot air furnace, hot water of either class, or steam, may be employed by being placed below, and the air delivered from the air chamber which encloses the tubes or other radiating cavities into the apartment in which it is to be used; or secondly, by the air supplies being admitted to the air chamber of the apparatus in the room itself; or thirdly, a part of the air may be partially warmed and admitted for ventilating, while the remainder of the needed supply is furnished by some disconnected heating means, as open fires, water stoves, steam pipes, or otherwise; or fourthly, the apartment itself may constitute the air chamber to the furnace, and the air of ventilation be admitted in a natural state from outside, to mingle with that artificially warmed. The objection to all arrangements involving this latter peculiarity is, that cold and warm air do not mix readily; and in this direct plan of admission, cold draughts can hardly be obviated.

The modes of managing the heating by mild hot water and steam, the most salubrious and agreeable of all methods, comprise a most extended variety.

The advantages of steam are the less extent of radiating surface required, the surface being always kept up to 212° F., while hot water cannot be maintained in practice above from 180° to 200°. Steam can also be more rapidly brought into action, the elastic vapor pressing the moment it is generated into the most remote part of the apparatus, while the circulation of hot water is gradual. By increasing the pressure of steam its temperature is increased, so that in very cold and urgent weather, a boiler capable of sustaining the usual pressure may be depended upon to furnish steam of a temperature and consequent power of radiating heat, considerably above the boiling point; for example, under a pressure of one and a half atmospheres, or 22 1-2 pounds to the inch, the temperature of steam is 240° F., under two atmospheres or 30 pounds, the temperature will be about 250°, still short of any scorching liability.

The advantages of warm water are, that its circulation goes on long after it is below the boiling point, which accommodates its action to the moderate demands of certain seasons.

It is again necessary to refer to our Appendix for a recapitulation of many of the practical details connected with these forms of heating and resulting ventilation, as well as for tables indicating the extent of the respective apparatus to produce a given result.

III. We find as the next common characteristic of modern ventilating arrangements, some method of diffusing the air, or spreading and breaking the entering current into divided streams, instead of permitting its ingress at a single point or in few openings, which when it is cold form unwholesome draughts, and when heated are equally uncomfortable and deficient in uniformity of condition, failing to give an equalized, homogeneous atmosphere of the proper character; nor does the column of air mingle with that present in the apartment.

Dr. Reid introduces what he terms a *mixing chamber*, under the apartment into which the air is to be admitted as it enters the reservoir; the current from the heating apparatus impinges against a flat surface placed a short distance above the orifices of admission, which he terms a *deflector*, and which throws it horizontally. This destroys its tendency to enter unequally at different points and aids its admixture with cool air, admitted to temper the medium as required. From this reservoir it is admitted by a vast number of small orifices, as we have seen, and is still further divided by a porous hair-cloth carpet. This method of making a hot-air reservoir under the whole room or by channels in various parts of it, and small openings through the risers of steps, beneath the seats, and similar unoccupied places, is quite general in these edifices, where sudden changes in the numbers of those present demand a rapid adaptation of temperature. The diffusion, as we have also seen, is occasion-

ally effected by reversing the current of air as it enters at the ceiling, by the action of a lively draught from near the floor, and thence proceeds upward into the attic, or descends perpendicularly to a common flue in the cellar.

Several simple experiments demonstrate how little the passing currents can be relied on for an admixture of the fresh air and warmed supplies. The stream of air admitted at an opening in the wall, can be clearly traced by a lighted candle at both its upper and under margins, till it strikes the top of the room and thence to its place of escape. Or we may notice how slightly the motion of persons passing about a room, or dancing with considerable activity, occasions any waving motion of the candles. Still more is this exemplified in the imperfect method in use in our hospitals for the insane, where a current of hot air enters and escapes without removing that lowest test of impurity, recognition by the olfactories.

IV. Another, and by far the most important essential, which we find in our various adduced illustrations of scientific and successful ventilation, consists in the invariable provision for some active, continuous, controllable, motive power, by which a current of air is maintained through the occupied space. This power may be arranged to exhaust the vitiated stratum, and thus have the partial vacuum filled with pure supplies through atmospheric pressure, or its action may be to propel in the fresh air, driving it before that already respired and depraved.

This mechanical provision we have found to con-

sist of various contrivances, acting in both these modes and on different principles.

The motive force is derived from the rarefaction of air by a fire in some portion of a tall shaft or chimney, under a variety of modifications all involving the same principle, the ascent of rarefied air and its consequent tendency to produce a vacuum, and all effecting the same result but adopted as economy, convenience, or caprice may have dictated.* We have seen the fire sometimes at the lower extremity of the shaft for the final escape of foul air, the flues turning their draughts received from all quarters under and around a fire-grate; sometimes the fire is arranged towards the middle so as to be fed from the very apartment ventilated, and more frequently still in the attic. The fire employed as a motive power is at times expressly for this end; at others it is that used for heating and other purposes; or the first of these methods may be relied on in summer, the latter in winter. The foul air may be turned directly into the chimney or smoke shaft, or into a flue contiguous to it, or a succession of foul-air flues communicating with different apartments may surround the chimney flue as a centre.

We find in many of the recent applications, that the foul-air flue is carried up in contact with

* For some illustrations of ventilating shafts, as respects the position of the fire grate, see Fig. 12, Pl. II. which explains itself. B represents the chimney shaft, C the fire, A the main foul-air flue from the inhabited apartments, D the door to feed the fire, E the ash pit. In the right hand diagram, the smoke passes up in an interior funnel or cast-iron pipe, and the air of combustion is admitted from the outside, instead of being taken as in the other examples, from the foul-air drain.

the smoke chimney until a point is reached at which no more collateral flues enter, when the *withe* or partition is left out. The expansion and ascent of the smoke and vapors aid in increasing the rarefaction below.

Occasionally a large mass of chimney flues, built to serve many fireplaces in the same house, has been replaced by a foul-air flue, and a central cast iron smoke flue, with lateral elbows to supply the fireplaces, has been introduced. The ventilating connections are made from each room in the vicinity, from top or bottom as preferred.*

In constructing chimnies for receiving foul air with the fire within them, it is hardly necessary to observe, that a greater power will be obtained by having them of circular area and of a conical shape or gradual taper, as the ascending current as it rises, diminishes in density, and eddies naturally diminishing its exhaustive power are produced. The amount of rarefaction and consequent draught will depend of course upon the size and length of the chimney and the amount of fire which may be in combustion.† These are susceptible of a

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* Appendix C.

† The use of chimnies already in operation for other purposes is frequently adapted to valuable ends in ventilating. A few years since, a long building in Glasgow, divided into tenements for five hundred workmen, was from its dirty and ill-ventilated condition, frequently visited by fever in its most fatal types. The superintendent of the mill to which these dwellings were attached, placed a large iron tube along the whole range of these houses, one end of which was closed while the other was built directly into the chimney shaft of the engine. At proper places in each house, tin tubes, an inch and a quarter in diameter, extended horizontally and were made to present an open extremity over the bed of each room. The register, closing the chim-

certain approximate calculation, the elements of which have been often theoretically demonstrated.*

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ney of the engine, was so connected to the fire damper, that on stopping the work, the valve was opened, and of course an active current of air was drawn from each room, to be replaced with presumptively purer supplies.

Since this powerful ventilating arrangement (considering its size of pipes) was provided, — which is described in Ure's Philosophy of Manufactures, p. 394, — these factory houses have been free from fever.

It is stated in the report of the Health of Towns Commission, that the Glasgow Fever Hospital is ventilated by a similar arrangement of pipes of a small calibre opening over each bed. While such arrangements are worth recording, as illustrating a principle, or even an ingenious adaptation where more proportionate aids are impracticable, it is hardly necessary to suggest that so small an egress pipe, and the absence of any provision for a proper renewal of the air withdrawn, are incompatible with the idea of any scientific ventilation.

There are also many instructive examples, arranged by ingenious persons, of connecting the seats of water closets with unemployed flues in the chimney stack producing a lively current downwards and totally nullifying any offensive exhalations.

I have been gratified to observe in a popular and wide-spread agricultural periodical some time since, plans for cheap farm houses, embracing a costless, simple, and efficacious provision for removing the foul air and dampness of cellars. It is well known to every practitioner in farming districts, that the cellar is usually the store house of many of the animal and vegetable products of the farm, and becomes, from their slow decomposition, the source of endemic fever, as well as of unpleasant effluvium. In the diagrams referred to, a single flue is carried up between the smoke flues and opening with these at top, while below it opens into the cellar. The constant heat of culinary operations and other purposes communicated to the air flue produces a current easily controllable by a lid or valve hung on hinges. To prevent the freezing which would result from the cellar being supplied with the external air in certain extremely cold periods, an opening into the kitchen might be necessary. The principal call for an active purification is, however, towards spring, when the danger of frost is least pressing.

* The principle and methods of calculation of the draughts of chimnies heated directly or by contact with smoke flues, in producing a ventilating or exhaustive suction of vitiated air, are plainly shown in Dr. Wyman's Treatise and Mr. Hood's work.

The primary force is the difference in weight of air, occasioned by the heat. Air as well as other gaseous bodies is subject to the law, that each degree of heat added from 32° to 212° F., increases the volume 1-480th.

"If this column of air [in a ventilating chimney] be ten feet high, and have its temperature raised 20°, then it will expand 20-480ths, or 1-24th of its bulk; so that its specific gravity would be diminished, and it would require a column of air ten feet five inches high, to balance a column of the

2. Another mode of obtaining an exhaustive power consists in a rarefaction of the air in the

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external air ten feet high, when the temperature of the latter is 20° lower than that of the former. But as the height of the heated column is limited by the height of the tube or chimney, which we suppose to be only ten feet high, the colder column presses it upwards with a force proportionate to this difference in weight, and with a velocity equal to that acquired by a body falling through a space equal to the difference in height, that two columns of equal *weight* would occupy, which in this case is five inches. Now, the law of gravitation is this: — that the velocity of descent is relatively as the square root of the distance through which the body falls; and as a body falls $16\frac{1}{2}$ feet in a second (or sixteen feet neglecting the fraction), the velocity will be, agreeable to the well known law of gravitation, equal to eight times the square root of the height of descent, in decimals of a foot; or $2\sqrt{g\,h}$, when g is the distance through which a falling body descends in one second of time, namely, 16.09 feet, and h the height of the descent.

In the case we have supposed five inches is the height of the effective descent of the heavy column of air. This fall of five inches is equal to .416 of a foot; therefore, by the rule, $2\sqrt{16.09 \times .416} = 5.174$ feet per second or 310 feet per minute, will be the velocity with which the heated column of air would be forced through the tube or chimney under the circumstances we have supposed. If therefore the tube were one foot square, there would pass out three hundred and ten cubic feet of air per minute." This rule, however, would be subject to the modifications of friction, curvature, chemical changes, &c.

In practice, after all, the height and dimensions of a chimney for producing a ventilating current, must be reached experimentally; for the many qualifications and modifying circumstances would prevent any calculation from being of direct utility.

The ventilating chimney of the houses of parliament with which Dr. Reid's experimental trials have been made, and which was equal to a supply of thirty or forty cubic feet of air per minute to its thousand persons, is one example. This chimney was one hundred and ten feet high, twelve feet diameter at base, and eight at top. In the ventilation of the Butler Hospital for the Insane, calculated for about one hundred and fifty persons, with a downward ventilation in all three stories and to an exceedingly thorough extent, it was expected that the smoke flues of the kitchen, bakery, steam engine for pumping, and in winter that of the boilers for generating the steam for heating — the whole carried up in a flue occupying twenty feet area, to a height of about seventy feet — would have, by contact with flues of about the same area and of the same elevation connected with the vitiated air flues, produced a perfectly certain and adequate effect. At least this was the judgment of some of the most competent English engineers with whom I conversed on the plan.

eduction or foul-air flues, by means of heat from radiating surfaces of pipes or plates within them,

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Precisely this original arrangement is to be carried out in the new Asylum for the Insane at St. John, New Brunswick.

As a general rule in modern styles of architecture, it will rarely be found that a central chimney need be carried higher than good taste would permit, in order to effect a thorough ventilation. For in the event of its proving on any occasion or at any season not equal to its expected duty, a little additional force, in the shape of an anthracite coal fire at the base of the ventilating chimney would meet the emergency.

Where many rooms are to be ventilated, as in a hotel, of various sizes, it would be found best to arrange the main stacks of chimneys so that several flues for ventilating should surround that into which the smoke of the constant and large fires for cooking and similar purposes is received. Then at the base of those connected with apartments which might be called into use under occasional exigencies, as halls, large reception rooms, &c., should be an opening to permit more exhaustive force to be added. Or even the steam of the boilers, now in almost universal use in large establishments, could be directed into a principal foul-air flue, according to Mr. Bell's system. At the McLean Asylum the waste steam of the small engine is turned into the foul-air flue of two of the least ventilated galleries. The noise which was feared as a serious objection proved quite inconsiderable, and the amount of upward current was probably increased tenfold when the engine was in operation.

In another instance at that institution, an underground horizontal flue was run from beneath the seat of a water closet, from which it was impossible to effect a removal of foul air by other methods, to an unused flue in the kitchen chimney stack, a distance of twenty-five or thirty feet. The effect was most decided; even the smoke of the most fœtid substances burnt in the pan of the closet, never ascended above the level of the seat. As a general rule, it is undoubtedly best to make a ventilating chimney as high and as large as is consistent with economy of space, cost, and symmetry of exterior. In school rooms, counting houses, lecture rooms, and the like, double the extent of the smoke flues may be expected to accomplish the ventilation.

It would seem to be proper to make some reference to one objection to the use of exhausting chimneys in ventilation which has attracted sufficient attention to be at least thoroughly refuted, — an attention not so much due to the soundness of the objection, as to the scientific character of the objector. Dr. Ure, the chemical philosopher, in his Dictionary as well as in his parliamentary evidence, and in announcing his views in other places, has asserted the opinion very confidently, that the exhaustive methods in ventilation produce a rarefaction of air most deleterious to health. In his impatience at Dr. Reid's experiments, he observes: "These curious effects clearly illustrate and strongly enforce the propriety of ventilating apartments by means of condensed air, and not by air rarefied by large chimney draughts,

containing steam or hot water. We have found these as long since as Dr. Desaguliers' trials in England in the last century, and we still notice them in some of Mr. Sylvester's latest improvements, and recommended by him in the great Parliament-House undertaking.

The forms of calorifers or hot-air furnaces, in which the tubes admitting the air below and allowing it to escape above at a high temperature are enveloped in the burning coals and attain a red or white heat, would be exceedingly convenient to effect this object, especially where no fear existed of fire being accidentally produced by the dropping of coals below, as might occur when wooden flues entered the ventilating chimney. Here the air furnace or calorifer, placed within the shaft and fed from without, would allow the air to pass through its heating pipes with great velocity. It is, in fact, all the use that such unhealthful and overheating appliances should receive. In one of our figures an early application of this plan is delineated.*

In the costly Maison Royale for Lunatics, at Charenton, we have seen that the hot-water pipes

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as has hitherto been most injudiciously, wastefully, and filthily done in too many cases."

The simple fact that the diminution of atmospheric pressure through any of the exhaustive methods, is stated by Mr. Hood seldom to exceed 1-100th of an inch of the barometer, and generally does not reach 1-200th of an inch, while the ordinary meteorological changes of this instrument, still unfelt upon the animal economy, run through more than two and a half inches, demonstrates the exceedingly "thin air" of Dr. Ure's hypercriticism.

* Fig. 5 and 6, Pl. I. are representations in elevation and cross section, of a calorifer long since employed to produce eduction. *n* is the reservoir for

are carried longitudinally through the escape flues, to induce the escape of foul air, in their way towards the points where they are expanded into suitable radiating surfaces. One of the applications of Perkins's high-heated pipes of water accomplished this result. The direct pipe which connected the radiating coils in different stories was carried through an upright flue, which had openings made to allow the air to be drawn in at suitable points near the floor to the ceiling as preferred. A stop-cock was placed near the point where the horizontal pipe left the perpendicular which cut off the circulation designed for heating, but still left it free in the pipes within the flue. This of course secured a ventilation in the season when it was too warm for artificial heat.

In the New Jersey State Lunatic Hospital, a discharge current is to be promoted by a steam pipe between one and two inches in diameter running the whole length of the foul-air flue perpendicularly. It will probably be found expedient to fit a jet apparatus to the upper end of this pipe and secure an upward draught on this recent application.

The rarefaction in the eduction flues is produced also by chandeliers suspended just below the inferior openings, as in the French Chamber of Peers, and in most modern theatres where a systematic

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feeding; *k*, the fire grate; *a a*, the tubes, surrounded by the flames; *c*, *c*, *c*, *c*, tubes which bring the foul air from various places into the common box, *d*, through which it ascends into the chimney, *o*.

ventilation is provided. Single lamps or Argand burners have also been hung within flues to meet particular emergencies, but would be too expensive a method for any extensive employment.*

3. The provision of a chamber, or an expansion of the foul-air flue just over the apartments to be relieved of their vitiated contents, which shall be supplied with a portion of the hot air generated for heating purposes in the basement below, is characterized by Mr. Brande in his Parliamentary testimony in 1835, "as the most generally and conveniently applicable method." Its modus operandi is obvious; the air below rushes up to fill the space above, in which the air is of less density.

4. Centrifugal or fan wheels acting either as exhausters to suck out vitiated or propellers to force in pure air, — which conditions of their action are respectively determined as before indicated by the circumstance of their centre or their periphery being connected with the entering or exit channels,— have been used from an early period and with satisfaction in some of the greatest examples, as is still the case in the French Chamber of Deputies. The formulæ by which the efficiency of these valuable machines may be calculated will be found below.†

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* Fig. 7, Pl. I. represents the chandelier *a*, surrounded by the metallic cone *b*, which is inserted into the shaft *c*, into which the foul air from various points is turned through the boxes *o* and *n*, and into the open air by the cap *u*.

† The method of determining the efficiency of the rotary fan is thus given by Mr. Hood: —

"The mean velocity of the portion of the vanes of the fan by which the

5. The employment of exhausting and propelling pumps and bellows is still maintained very efficiently in certain large establishments, an example of which we have introduced.

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air is discharged, is about $\frac{7}{8}$ of the velocity of the extremities of the leaves; but owing to the inertia of the air, there will be a further loss in the velocity of the issuing current, increasing with the greater velocity of the vanes; so that, under ordinary circumstances, the current will be discharged with a velocity equal to about $\frac{3}{4}$ of the velocity of the extremity of the leaves. This velocity in feet per second, multiplied by the area of the discharge pipe in square feet, will give the number of cubic feet of air discharged per second.

To estimate the force necessary to cause the rotation of the fan, the following method of calculation, founded on the ordinary mode of estimating steam power, will be found sufficiently accurate:—

Suppose the effective velocity of the vanes of the fan to be 70 feet per second, and the sectional area of the eduction tube to be 3 square feet, then $70 \times 3 = 210$ cubic feet will be the quantity of air discharged per second; and this number, multiplied by 60, will give the quantity per minute. As a cubic foot of air weighs 527 grains, there will be about 13 cubic feet of air to a pound; therefore $\frac{210 \times 60}{13} = 969$ lbs. is the weight of air put in motion per minute, with a velocity of 70 feet per second. The height from which a gravitating body must fall, in order to acquire a velocity of 70 feet per second, is $\frac{70^2}{8^2} = 76.5$ feet; which, multiplied by the number of pounds weight moved per minute, will give the power necessary to be expended, in order to discharge this quantity of air at the stated velocity. And this product divided by 33,000 (the number of pounds weight that one horse will raise one foot high per minute), will give the amount of steam power required. Therefore $\frac{76.5 \times 969}{33,000} = 2.24$, or nearly $2\frac{1}{4}$ horse power, will be necessary to discharge the given quantity of air at the velocity stated."

Fig. 22, Pl. II., represents an improved form of the fanner, as compared with the construction of Dr. Desaguliers and others. The case and the interior wheel are not concentric: *o*, *o*, is the case; *a*, the axis; and *c*, *c*, *c*, *c*, the vanes; *d* is the channel through which the air is forced in the direction of the arrows; *x* marks the central openings in the ends of the case, for the induction of the air.

In the application of fan wheels for ventilation, it must not be forgotten that the quantity of air, not its velocity and pressure, is the object sought; the reverse of what is required in blowers for facilitating combustion. A speed of 3 to 500 revolutions per minute, is as much as can be maintained without an unpleasant noise; and, in view of all the loss of power in gearing, &c., the diameter of the fan should be calculated for a speed, certainly within that named.

The curvilinear blades of some modern varieties have no superiority sufficient to counterbalance the mechanical disadvantages.

The reciprocating action and friction of packing, as well as the loss of power resulting in most forms from *wire drawing* the air, as it is called, that is, forcing it through a diminished aperture, prevent this from being as economical a method of using power, as the centrifugal wheel. There may, however, be situations in which it may form the most desirable apparatus.*

Dr. Arnott, in his testimony before the Health of Towns Commission, observes that when he visited Glasgow in company with Mr. Chadwick, there was described to them a vast lodging house in connection with a manufactory, in which fever was formerly very prevalent, and which was in consequence ventilated by making an opening from each room into a duct which terminated in an air pump. The supply of pure air, he says, obtained by that method of ventilation, was sufficient to dilute the cause of disease, so that it became powerless.

6. The use of the steam jet, the latest and probably the least troublesome and most certain of the

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* The effective performance of blowing cylinders for this purpose, under a given amount of moving power, is readily calculated.

"Suppose a ventilating pump three feet square and five feet high, and that the piston makes twenty-five double strokes per minute, each four and a half feet long. In this case, 2025 cubic feet of air per minute will be discharged; and if a valve for its discharge be ten inches square, the velocity of its discharge will be equal to 48.6 feet per second. This quantity of air, reduced into weight, will be $\frac{2025}{13} = 155$ lbs. put into motion every minute, at the rate of 48.6 feet per second; and therefore, we shall have $\frac{48.6^2}{8^2} = 36.9$ feet, as the height from which a gravitating body must fall, to obtain the velocity of 48.6 feet per sec., and $\frac{155 \times 36.9}{33,000} = .17$, or one-sixth of a horse power, as the necessary force to discharge this quantity of air, at the stated velocity."

It will be recollected, that a horse power in dynamics is 33,000 pounds, raised a foot per minute.

methods of inducing an exhaustive current, has been described in the account of the new Houses of Parliament.

Steam has been before used in locomotive engines, to produce the prodigious draught needful in their rapid combustion of fuel, by the escape pipe entering the chimney.

The only exact statement of its efficiency I have seen, is the calculation of Mr. Faraday, that with the steam at thirty-two pounds pressure to the inch, or about two atmospheres, a point not unusual in what are deemed *low pressure* boilers, air is removed to the amount of two hundred and seventeen times the cubic feet of steam escaping.

The jet is arranged in the simple and economical circular cap, such as constitutes a very common form of gas burner.* No particular length of shaft is required into which the steam is to be liberated, and the foul air is received below.

7. The use of revolving screws of various forms, to exhaust and propel air as they may be turned one way or the other, requires to be mentioned only to put those disposed to invent new things on their guard and lead them to examine what has been hitherto done.†

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* Fig. 24, Pl. II.

† Dr. Reid observes that the Archimedean screw has been extensively used in Belgium and elsewhere, as a substitute for the fanner or centrifugal wheel. Several years since, two gentlemen of nearly the same name, — Mr. Combe of Leeds, and M. Combes of Belgium, — made an improvement in the screw simultaneously, to which Dr. R. is inclined to give the preference over the preceding varieties. Fig. 23, Pl. II. represents one of the varieties of this form. The *double screw* is convoluted spirally around the axis *c*,

V. Our last common essential is in the power of controlling and regulating the operation of the apparatus, producing the ventilating change. It is obvious that the various circumstances of numbers, character, and detention of the occupants, and the state of the external air, must require a command over any apparatus or method, to fit it for proportionate action. An extent of warming and ventilating adapted to a full Parliament of eight hundred or a thousand persons, during an interesting and exciting debate, would be widely unfit for the faithful few who might remain after it was over to plod over the dull details of private bills or financial statistics.

So the amount of air which would be fully adequate to the ordinary wants of a hospital, would be wholly unequal to a pure and salubrious atmosphere in the parts devoted to fever, small pox, gangrene, and the like. The galleries of the convalescent or cleanly patients of a lunatic asylum require an insignificant quantity of fresh air, compared with those occupied with the demented or maniacal, lost to personal propriety. Apartments occupied for a few hours or a single hour, like lecture-rooms, churches, and the like, would permit a much less energetic provision of machinery than if the sessions were protracted, as in courts of justice, schools, and legislative halls, while the

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which is turned by any motive power at hand. A shifting of the gearing so as to reverse the direction will change its action from propelling to suction, at will. The arrows show the respective directions of the screw and air currents.

latter have intervals of repose unknown to prisons, hospitals, and other places of detention, where the inmates are present through the day and night.

All these adaptations are to be provided for, and in most of our examples we see the most abundant means of meeting every emergency. The tables of the temperature of the House of Commons and the prisons on the Model Plan, (and this element perhaps expresses the renewal of air in those instances where the only heating is in the air of ventilation,) demonstrate the accuracy to which the adaptation is brought. It is hardly too much to say, that in them the quantity, the hygrometric condition and temperature of the air are susceptible of as much exactness, as the provision of food and drink.

In the recent ventilations of the principal Parisian edifices, a contract providing for all the requisites of a perfect system is entered into, and even the precise sum for the annual support of these arrangements is agreed upon. In Péclet's complete treatise, various specimens of the accuracy to which this part of the detail has arrived are presented. A practical tradesman agrees to furnish without fail, a certain number of cubic feet of pure air, per minute, at a given temperature, at a specified sum.

A maximum supply may be contracted for, while the power of reducing this to a less degree required by the circumstances of the case, is placed within the ready control of a moderate degree of intelligence. It is of course not within the com-

pass of possibility, that there can be any self-regulating means of supplying heat or air, where the demand is continually varying. Hence all systems on any considerable scale, must require a constant supervision, and management on fixed principles, and not as suggested by the capricious and uncertain calls of individuals of peculiar constitutions and habits. Much of the obloquy and ridicule which have fallen upon Dr. Reid and his ventilating trials, has been owing to the impossibility of satisfying men, whose requirements are widely variant or even diametrically opposite. The rubicund four-bottle country squire and the exsanguined and aged ecclesiastic, cannot be measured by the same scale without one or the other suffering. An approximation to the average necessities is all that can be hoped for.

In most of the provisions of motive power, the controlling means are obvious. Valvular contrivances, known as registers or dampers, are equal to the smaller adaptations or temporary emergencies. The amount of fire or steam, or other heating means, when these constitute the moving force, the velocity of the fan-wheel or other apparatus involving the same principle, are all readily adapted to a very low minimum. If in the original arrangement, a plan is carefully calculated for a high maximum, as measured by the number of cubic feet of air thrown in or drawn out, there is little difficulty and usually but little wasted expenditure, in working the apparatus at a much diminished activity,

The various modes of effecting the same results in ventilation, are by no means to be considered as antagonistic or even competitory to each other. An abstract preference cannot be properly yielded to one at the expense of the others, as an inferior machine in the arts yields place to one of an improved design. The selection of a system or of peculiar features of several systems, will depend entirely upon circumstances. The degree of perfection sought in some cases, as in the plans of Parliamentary Halls and certain hospitals, demanding the utmost of hygienic completeness or even luxurious provision within reach, may be allowed to overrule all considerations in the points of cost of construction or of maintaining in due performance.

The occasion as determined by the extent of numbers to be provided for, their character, and their continuance in the same place, is also an important element in deciding the question. A library, a church, a hall of assembly for concerts or lectures of an hour, a school where a small portion of day-time only is spent, a legislative hall of uncertain numbers and length of sessions, manufactories of high temperature, offensive processes and crowded population, hospitals for numbers of the sick or insane, equally pressing at night as at day, all constitute in an increasing ratio instances of the inequality of the extent of provision required.

The presence or absence of an available power of steam or water to give motion to ventilating ma-

chinery, may give a preference to certain arrangements, entirely out of the question under other circumstances.

To illustrate these modifying conditions, by particular instances: Were it determined to ventilate a large already finished hall for lectures, concerts, or other evening occasions of an hour or two duration, the simple rotary fan, propelled by the labor of a man, arranged in the garret or cellar as it might be preferred to inject fresh or exhaust foul air, would involve least expense, least complexity, least disturbance of work already completed, with a sufficiently complete performance of its office.

If, again, we were required to provide perpetual, certain, and copious changes of air for a large hospital for medical or surgical diseases or for the insane, or for a cellular prison, where no power would ordinarily be at hand, little doubt can exist that the lofty chimney shaft, urged by a coal fire or the late adaptation of the steam jet, would be the most reliable as well as the most economical. Here again, circumstances would decide which modification of the many plans having the tall shaft for their motive power should be selected.

Whether the flues for foul air should surround the central smoke flue or enter at its foot under and around its grate, whether the foul air flues should proceed upwards or descend to their horizontal main channel, whether the common fires for culinary and heating purposes should be relied upon,

or a separate fire be provided, and many inferior points would all be decided by the position of each case. For some hospitals, hotels, or prisons, the kitchen fires might prove adequate; for the larger class of hospital edifices, an independent shaft of lofty height would be demanded.

Again, to purify the populous halls of a factory or other building for the purposes of the arts, where from the aggregation of the employed or the nature of the processes, a lively and energetic ventilation would be requisite and where abundant motive power is at hand ready to be used as long as the necessity obtains — that is, by daylight only — the fan wheel or wind cylinder in some of their varieties, might be more expedient.*

Where the steam engine or merely the steam boiler for heating is found, as is the case in most of the immense modern cotton factories of New England, the jet of steam thrown into the eduction channels might be the most useful mode.

A downward ventilation, that is, from or near the floor of the room, requires more power and consequently is at some economical disadvantage, by the reversing of the naturally ascending movement. But in halls where the dust raised by the feet of an excited auditory may better be kept from their lungs, — in insane hospitals, where the inlets if accessible may be polluted, and indeed are con-

* The ventilating fan is said by Mr. Bernan to be much used in the manufacturing districts of England, for drawing off the heat, moisture, and filamentary dust of the rooms.

stantly liable to annoying depravations from the use of tobacco or other filthy practices, these become harmless from the current of air being drawn outwards, not inwards over the offensive matters;—in legislative halls and court houses, where according to the custom of our country an infusion of the same vile weed is scattered over the floor so profusely that as its vapor rises in universal solution, no man with clean interior can hope to escape imbibing an equal share of the offensive fumes, a draught downwards with a pure admission of air from a point overhead, is certainly a great desideratum. Indeed, the plan of a united upward and downward ventilation at the same time, to meet some exigencies in the arts, is recommended in some modern treatises. So refined and nicely equilibriated an adjustment as this would seem to require, could scarcely be maintainable in practical application.

It is thus obvious, that in deciding upon the details of any plan, the general principles of the art must be well understood and applied in view of all the circumstances of the given case.

For a numerous proportion of the exigencies which present themselves in every day life, such as school-houses, poor-houses, lyceums, and other halls, vestries, court-houses and small county prisons, my impressions are in favor of main foul-air flues, passing up in contact with smoke flues in constant use; or in case of hot air furnaces being employed, the foul-air duct should be between both these warming sources, the *withe* or dividing partition

between the smoke and foul-air flues being removed at the attic floor to augment the draught.

For summer use, in case the kitchen or other fires are diminished or discontinued, an opening for a fire with a grate should be made at some convenient point in the foul-air flue. The point for a moderate fire of some slowly burning fuel for this purpose ordinarily the most convenient, is in the cellar where the furnace is, but may be in the attic as figured in the plan of the Pentonville Prison, or even in the apartment itself as delineated in the French school-house.

The main foul-air flue, placed either within or just outside of the apartment, may be pierced for the admission of vitiated air at such part as is deemed most expedient, in accordance with the system of upward or downward ventilation determined upon.

If the supplies of warm or fresh air are from below and admitted at the floor, the foul air would properly be drawn off at the ceiling, either by a single opening as large in area as the tube would permit, or by lateral flues running horizontally across, around, or just above the ceiling, (a box-like cornice for example,) and apertures to equal the flue-area made in these at convenient distances.

If the heating is provided by flues opening high or by radiating pipes or stoves, the foul air may be drawn off at a similar opening at the floor of the room into the foul-air duct.

Or if it is decided to protect the lungs from the

dust and vapors by a downward current, horizontal flues beneath the floor should extend from many parts of the room, with perforations into them at every point protected from closure, arranged as respects size and frequency with a constant regard to the comparative indraught, at different distances from the upward flues.

In a climate where so much wind exists as in ours at certain seasons, I would not wholly discard the use of turn-caps, for aiding in admitting and discharging air. These, of course, are merely auxiliary measures, calculated to save some expense in motive power; as no one acquainted with the demands or completeness of modern ventilating arrangements, would even think of relying exclusively or mainly, upon any contrivance depending on so proverbially inconstant a power as the wind. For, as before intimated, there are occasionally weeks of most imperious demand, when the cowls or caps are actually worse than merely useless.

The cast-iron *plenum* and *vacuum* revolving cowls constructed by Mr. Mott of New York and used in the public schools of that city, and the fixed cap with a conical border, originally constructed in 1788 by St. Martin (the best form of which is that recommended by the American Academy of Arts, in the Report heretofore referred to), appear to me to comprise most that is attainable in that multitudinous class of contrivances, in the cheapest and most durable form.

Our last subject for consideration is the quantity of change of air which is necessary or expedient.

In arranging the ventilation of any given habitation, how many cubic feet of air should be thrown in and taken out, in order to secure the full advantages of health and comfort, dependent on purity of the respiratory medium?

In estimating the quantity of air required for each pair of lungs in a given time, neither chemistry nor physiology, as before intimated, affords us any aid. Were the question — how much air is needful to save from suffocation? the researches of the chemist as to the decomposition of ascertained averages of the amount of air in the lungs, would be sufficiently precise and reliable. But when we consider that the comparatively minute taint or imperfection from the effect of respiration, is capable, under most extended dilutions, of producing an undoubted deterioration upon the hygienic and sanatory qualities of the atmosphere, we shall see how little any chemical alterations bear upon the infinitely more delicate, and as it were, spiritual depreciations. If analytic chemistry is still too coarse in its investigations to be able to detect any difference in the pure mountain breeze, and the stifled contents of the small-pox or fever hospital, — if the mere senses can detect repulsive additions which tests do not recognize or verify, it ought not to be blamed for failing to throw light upon so infinitesimally small dilutions of respiration. We know by the abundant proofs suggested heretofore, amounting almost to

demonstration, how momentous the inappreciable additions are, as respects disease and death. If no scientific acquisitions enable us to find out these important relations, neither do our senses give us warning or defence. A single respiration from the lungs will produce a medium in which a candle will not burn ; yet within my own personal observation, Irish laborers have continued at their work at the bottom of a well, hours after a light had been extinguished.

A depraved taste as to the quality of air can be acquired and maintained as well as in regard to food or water, of which so many examples will occur to almost every one. One of the oldest and most honored of our Supreme Judges, who has been seated days and years in court-houses filled with the most polluted and irrespirable atmosphere to all unaccustomed lungs, avers that he recognizes no defects in it, and regards all call for ventilating measures as quite superfluous, on his account!

We are then driven for the solution of the important question of quantity, to the result of experience, a test in a single case being quite too uncertain and intangible, but when reduced to the formulæ derived from the conclusions of many investigations, must form our standard, because it is the highest evidence the case admits.

Commencing with the lowest minimum proposed by the leading authorities, we shall find as we reach the highest maximum a wide range. Dr. Arnott considers two or three cubic feet a minute, as all that need be charged to each person. Mr.

Tredgold fixes his average at four. Mr. Hood, a recent very accurate and practical writer, observes, "that in all public buildings and rooms of dwelling-houses, a quantity of air equal to from three and a half to five cubic feet, for each individual the room contains, must be changed per minute, in order to preserve the wholesomeness and purity of the atmosphere." Mr. Toynbee, F.R.S., an English surgeon, in a lecture recently delivered before the Institution of British Architects, fixes upon ten cubic feet per minute, or, what he proposes as a unit of measurement, double the contents of a man's body, as required to meet the demands of respiration.

Dr. Reid declares that the provision of ten cubic feet to each person, per minute, in the House of Commons, proved to be a minimum which was generally recognized as below the natural wants of the system, and declares it as his determination, to adapt his ventilating power to the work of introducing not less than from twenty to sixty cubic feet per minute. In the French Chamber of Peers, twelve cubic feet are furnished. At the Pentonville Model Prison, the arrangements are fitted to turn in from thirty to forty-five cubic feet.*

With data like these, it would not perhaps be an

* The velocity of air in currents and in flues is measured, and its quantity in cubic feet determined, in various ways. Anemometers or wind-gauges, indicating the strength of the current by number of revolutions, or raising weights, or contracting a spring, have been constructed. The floating of flocculent particles or dense smoke, enables the speed to be noted by a stop-watch, through a given length of pipe or flue. Paper covered with a paste of starch, receiving a current of the vapor of iodine liberated at the other end of the channel, is struck instantaneously with a deep blue tinge. The interval is measured by any time-keeping instrument.

unsafe estimate to consider the quantity of supply demanded to maintain a due fitness of the air for respiration, at from ten to twenty cubic feet per minute, to each person. Circumstances may considerably influence any general conclusion like this. For example: in large rooms to be occupied only for short periods, like churches, it must not be overlooked that there is at commencement a reservoir of pure air in the space above, which is to be subtracted from the amount to be obtained artificially. Mr. Péclet calculates that each person fills $\frac{33}{100}$ of a metre, or about a foot of area on the floor. To contain a supply of air for a session of one hour, a room must then be fifty-four feet high, and in this ratio.

Again, in some cases of exceedingly uncleanly inmates or offensive diseases, the quantity of change demanded to maintain an atmosphere pure to the olfactories, must be more than the amount for merely respiratory purposes. Generally the contrary will be the case, and it will be found that the adequate supply for the lungs will prove sufficient to maintain a fresh, elastic, and unrecognizable condition.

On bringing to a close this brief consideration of a most important art, I would hope not to transcend the bounds of a respectful deference, in urging upon the members of this association the claims which the various branches of sanatory and hygienic reform and especially that of ventilation have upon their attention and investigation, particularly in their relations to the population of New England, at our day and *in futuro.* Have not these

been emphatically the omitted of the great questions of professional culture, the world over? Pathology, therapeutics, the profoundest secrets of healthy structure and of diseased change, have been pursued with a zeal, perseverance, and success so extraordinary as to mark our age as that of critical exactness and refined observation. The causation of disease, the prevention of the morbid influences in operation prior to either functional or organic response, the recognition and counter action of the subtle causes of commotions set up in the animal economy to expel or to contest with some morbific source of mischief, have necessarily been deficient in that element of numerical and specific exactitude, which commends itself to the accumulator of truths, and may therefore perhaps have been somewhat ungracious to the tastes of our time. These have consequently been rather allowed to fall into the category of loose speculations, and have been regarded as topics of a light and popular literature scarcely of the profession,—as presenting proper features for the magazine or the lyceum, rather than for the strict persevering research, accorded to other topics of medical investigation. Let it be thus no longer — let the physician claim as his own, these matters primarily bearing on life and disease, and save them from the unhallowed hands of merely popular sciolists, by a profundity and precision of knowledge respecting them, which shall overwhelm all merely superficial acquisitions.

The old world is roused to the consideration of

sanatory reform, by the pressing necessities of the case so urgent as to allow no further procrastination. Its governments have been awakened to the dire consequences in disease, deterioration of the species, and frightful mortality, of a neglect for ages of the laws of health and life, and are preparing to expend with an unstinted hand the stores of accumulated treasure, to redeem themselves and their posterity from the consequences of long perpetuated ignorance and error.

Be it ours to guide a new people, by the lights of past experience, and the world's present science, so as to avoid the same errors and omissions, and by consequence, the same disastrous results.

We are so fortunate as to live at an era, and in a country where, despite the forebodings expressed by the impatient and the desponding that the inroads of empiricism of a thousand names are endangering our profession and the society of our time, the character and judgment of the scientific, the wise, the practical physician are of greater weight than at any former period of the world's history. The throwing off the mere trappings and artificial distinctions of society now in progress in the other hemisphere, long since achieved with us, is only one of the resulting manifestations that mind, cultivated reason, and enlightened conscience, are destined to hold their just influence over the civilized world. Measured by such claims to first rank, by devotion to others' welfare, by abnegation of self, by perseverance *inter labores et tedia*, the followers of the

medical art have no reason to dread diminished consideration, as the world proceeds under its new system.

Gentlemen of the Society:

Happy should I regard myself, if I could close my short hour's communion with you, in these words of encouragement, congratulation, and hope. But alas, he that stands in this place, as year succeeds year, must have the melancholy, yet not wholly painful duty, of recalling to the living, the memories, the services, and the merits of the dead. I say that the duty of commemorating those who have passed on before us, is not unmixedly painful; for in the long years of useful labor of some, and in the abundant proofs in the shorter career of so many others more early removed, that

> That life is long, which answers life's great end,

— in the exulting consciousness we feel, that there are still spared so many of the fathers of our calling, who have so long filled the highest places in the public estimation as they have in our hearts, whose influence upon the elevation of the medical profession in Massachusetts, in New England, can be fully appreciated only in after times, — towards each one of whom, as year after year we greet their venerated forms on this floor, the spontaneous ejaculation bursts from our inmost soul, *sero in coelum redeas!* — we cannot feel that we grieve for the fallen of our ranks, as those without many circumstances of mitigation and of mercy.

APPENDIX.

APPENDIX.

A.

The failures of the ordinary modes of endeavoring to introduce a pure atmosphere into buildings and to sustain it under all circumstances, are quite numerous. Although any others than systems with an exhaustive power are considered so obsolete as not properly to come within a treatise on practical ventilation, and have scarcely been alluded to in the body of this work, yet as many persons are yet to go through the trial from necessity or ignorance, a recapitulation of the sources of failure may serve to obviate a portion of an evil, if it cannot be wholly averted.

I. Relying upon the opening of lateral windows. In all temperate and cold climates, glass windows are made to open either by the raising the lower sash, raising the lower and dropping the upper at the same time, or by dividing the entire sash in the middle while it opens from bottom to top on both sides. This last arrangement is known as the French window, and has become quite common in the most expensive class of houses in the Atlantic cities.

It has doubtless been noticed, that in all the superior examples of ventilation introduced, the windows have had no share in the process. They have been considered, as in fact they are made in practice, as fixed immovably. Experience has ever demonstrated that buildings in which open windows are relied upon, are never ventilated at all. In climates like ours, the cold gush of fresh air into a heated room cools, but does not materially change the vitiated atmosphere, while the effect of the draught upon the health is too well admitted to require a moment's consideration. The windows opening at top and bottom, by the sliding of both sashes, may in some cases, as in theory they are intended, permit the air to enter at bottom and the heated surplus to escape at the upper opening. The slightest moving current towards these windows annihilates all hopes of this, and the cold air beats directly upon the heads of the audience or inmates.

Again, during several weeks in spring and autumn in the northern parts of the United States, the weather is in that state in which it is too warm for artificial fires, and too cold or damp, or both, for open windows. Here, of course, is no ventilation. It also often happens in cities, that in public and private buildings, the open window admits odors, sounds, and even insects, to a degree rendering defective ventilation the lesser evil. Our courts of justice are striking illustrations of the difficulty of hearing, from the noise in streets, except at the expense of an atmosphere corrupt enough to hebetate the faculties of judges, counsel, and jury.

The importance of double sashes in economy of fuel and equality of temper-

ature, renders some method necessary in houses of the better class to avoid any reliance upon windows which, of course, cannot be opened for ventilation when so duplicated.

Pleasant as the open window certainly is in our dwelling houses at times in the summer months of our climate, yet it may well be doubted, in these days when the manufacture of glass has become so perfect as to impede no vision and so cheap, in view of all the maladies produced by this the most fruitful of causes, whether that will not be a step of the highest value in "sanatory reform," which renders the window sash a fixture. Certainly the noisome odors, the pestilential vapors, and annoying sounds of large cities, must render supplies of pure air from some other source exceedingly desirable. And in country residences the chilling draughts of windows accidentally or heedlessly left open, inducing a long catalogue of diseases dependent on checked perspiration, and the crowds of disgusting or irritating winged insects ready to approach the evening's light, overbalance the few opportunities of that peculiar enjoyment which the passing current of genial air affords.

It is hardly necessary to advert to the universally admitted fact that the draughts of air, impinging upon part of the person as they do in entering an opened window, are much more pernicious than a complete exposure without the draught. Open flagged and dry walks, open verandas, or even projecting balconies, are accessories to dwellings more than compensating for the opening or sliding sashes, without destroying, as these must do, all hopes of a regular, reliable system of ventilation.

For some important experiments showing the cooling power of windows, and the consequent value of the double sash, the reader is referred to Dr. Wyman's *Treatise on Ventilation*, p. 389.

II. The uncertainty and insufficiency of flues or passages with no other aids, leading from the apartment to be ventilated. Experience the most extended, of this the most common of all modes of effecting this object,—indeed the almost exclusive mode of attempting it in the public institutions of this country,—abundantly demonstrates that it is entirely unworthy of being considered as a true ventilation. Still there is some degree of efficacy in it, and there are various circumstances which influence its value, from its most considerable action down to the point of utter nullity.

Where flues are used to allow the escape of vitiated and foul air, the usual expectation is that the fresh supplies are to be received from furnaces below, from stoves or fires within the room supplied from the outer air into an interspace surrounding the fire, or from steam or water pipes also within it in winter or cold weather; and through other avenues during the rest of the year. The circumstances modifying and influencing the efficiency of foul-air escape or eduction flues, as they have been called, are:

1. *That the flues are of insufficient size.* Almost all persons who make their first experiment in ventilation overrate the effect which the flue will produce, and consequently make it of inadequate dimensions. Sir H. Davy, as mentioned in the text, was invited with a *carte blanche* as to the arrangements and the expenditures, to design a system of ventilating the English House of Peers (the present House of Commons). In his plan the area of discharge was only one foot. In the recent method this was augmented to fifty

feet. Nor was the difference explained by there being a greater motive power in the first case, for the reverse was the fact.

In most of the prisons of this country, both on the Auburn and Philadelphia plan, without now referring to other weakening circumstances, the discharging flues are made of an area of sixteen to forty-eight inches only.

In the insane hospitals, the uniform system, when any has been provided in the original building, has been to make the flues for the bed-rooms, &c. within the brick partition walls, which are a foot or three courses in thickness. The size, then, is consequently one brick or four inches wide, by a length once and a half or twice as great, or from forty-eight to sixty-four inches area, the orifice being perhaps expanded to twice those dimensions. Occasionally flues eight inches square are found in the McLean Asylum; in some hospitals the orifice is covered, for some unknown reason, with a perforated cover of iron, reducing its area to a very few inches, and in other cases a couple of inch holes only are left.

Our court-houses, school-houses, lecture-rooms, and other places of continuous congregation, have been fitted with outlets in this proportion, most commonly occupying the vacant portions of the ornamental centre-piece in the ceiling. This contractedness of dimension also existed with the openings for the admission of fresh air — warm and cold, when any such happened to be provided.

It is not uncommon under more improved methods to see the orifice of the warm air-flue (when the air does not enter in many places or in diffusion), from two to three feet square, and the underground passage for fresh air sufficiently large to allow a man to pass nearly upright to examine and remove any impurity, such as leakage of sewers, rats, cats, and the like, which might contaminate the air.

The discharge-flues are also made larger or more numerous. The principle now seems to be, that as all flues are so readily commanded and diminished by a simple flap or valve register hung on a central point, or by hinges at the edges, and turned by a handle passing through the wall, it is better to construct them of the fullest possible size. If originally made in brick walls or under ground of too limited dimensions, it becomes exceedingly difficult to enlarge them. In designing a plan for the Butler Hospital for the Insane,— one of a class of institutions requiring the greatest amount of ventilation,— it was calculated that the flues would fill the whole central walls, wherein they could be carried perpendicularly or nearly so.

In brick edifices the external wall may constitute flues for some purposes, and their presence increases the dryness of the interior without diminishing the strength of the masonry. In public buildings, unless the exact size is beyond prospect of change, and the internal divisions are as certainly permanent, and the system of heating and ventilation has been unchangeably determined upon, no loss and probably great ultimate convenience would be found in carrying the flues in every point where space will permit. If needed they could be pierced and used as induction or discharge-flues; if not called for, they would constitute a modification of the ordinary *vaulting* or air-space left in many first class constructions.

2. *Want of directness of ascent.* When a motive power is intended, this objection is of diminished importance, but reference is now rather had to the

spontaneous movement induced by mere diminished gravitation. So in passages where very highly-heated air is admitted or discharged, the great rarefaction may overcome this obstacle to a greater or less degree. In the mere power derived from the animal heat or common warming of apartments, a change of direction only a few degrees from the perpendicular seems to produce a series of eddies against the upper side of the pipe, which impedes the ascent.

If a flue has more or less oblique angles, as occasionally is necessary to clear doors or other openings in the wall, the same eddy acting like a positive impediment occurs. The higher up and less frequently repeated, the less will be its injury.

If the flue turn at right angles or pass horizontally, or with a second upward run, the draught will be proportionally impeded as the angles are more frequent and the horizontal portions longer. In most cases a bend twice at right angles, at ordinary temperatures, without enlargement of the horizontal section, and without exhaustive power, is nearly as fatal to the discharge as an actual closing of the flue.

3. *The flues are not of a figure and finish calculated to favor the upward ascent of a fluid like air.* A tube with oblong area, or even a square made with rough bricks, and without *pargeting* or interior plastering, gives rise to so much friction, that its actual performance falls far short of its theoretical power.

The most effective shape is the circular cylinder, next the ellipitical, then the square with bevelled corners, and so on, down to the narrow parallelogram. Air in its ascent is disposed in obedience to obstacles which affect it, to take a spiral motion. The more regular and smooth its tube the less broken will be the spiral motion; the friction will be less, and of course the discharge the more increased. The effect of rough surfaces or of air compressed into the angles of the flue, is not only to retard its speed and quantity directly, but, what is an important loss when feeble ascensive power exists, by this delay to give time for the current to cool, which also acts still more disadvantageously by increasing the gravity.

In forming air-flues of metal, they are naturally made round. A little increased pains and cost more than repaid in augmented efficiency, would also furnish them in wood or brick-work of the best form and surface.

4. *Flues are made in exterior walls*, and the air which is intended to be discharged in consequence of its elevated temperature and diminished gravity is so cooled down by exposure to the exterior cold, as to cease to ascend; or even a reversed action may occur in certain conditions of the weather. The absurdity of this arrangement of small square flues in outer walls, was strikingly exemplified in the ventilation of the sleeping rooms of the South Boston Lunatic Hospital. As has been before observed, if an active motive power is employed, the objection to foul-air flues in outer walls becomes of little or no consequence.

5. *Foul-air flues, in the spontaneous mode* (*i. e. with no power to produce motion*), *opening directly into the open air*, are not to be depended upon for an upward action. The usual custom resulting from this difficulty, is to have them terminate in the attic or garret, from which the communication to the open air is made through some form of cowl, Chinese cap, or louvre.

A simple valvular arrangement to prevent regurgitations in sudden shifts of the wind, or when if turncaps are used they are caught "on the centre" so as to face windward, is often introduced with great advantage. A mode long used in the McLean Asylum is found free from objection. Just below the escape opening in the ridge of the roof, a broad platform a few feet long is laid so as to cut off four or five feet of the apex. At each end this is boarded up, leaving an oblong space about four feet by two. Wires are placed horizontally and vertically across this space, making squares of eight or ten inches, to sustain the valve. The valve consists of common cotton cloth, suspended by tacks from its upper edge, while the lower or free edge is stiffened by a thin strip of wood. It is placed within the wires. The ordinary upward movement keeps this thin curtain raised before it, scarcely impeding the current. Any retrograde action at once closes the flap against the wire, and prevents any backward flow.

When the roof is slated, and indeed, though less urgently, in other cases, the attic should be plastered to prevent the sudden cooling down of its air to a point below that in the house, when, of course, the air descends.

6. *Any flues depending wholly upon the action of cowls or turn-caps* in any of their numerous forms, are totally unequal to the demands of a constant, reliable ventilation. Many of these are re-invented every few years, and there is not perhaps a single form of them which may not find its prototype, or exact example, in the patent repertories and philosophical transactions. The reader who has the slightest faith in these machines will find a great number of sketches of them in Péclet's complete treatise, in Dr. Wyman's work, and his Report to the American Academy of Arts, &c., or in the curious researches of Ewbank. This latter practical mechanic demonstrated by actual experiment, as respects the revolving varieties, so far as trials by models are demonstration, that of all the known forms, the most effective was the simple bent funnel a little swelled at its mouth with a vane. If it has a curved line at the back, it must also least impede the natural ascent of air, when no current exists, — a serious objection to all the others, that of diminishing the upward movement in calms by at least one right angle, and usually by the friction of the interior.

The simple fact in regard to those auxiliaries is, that during certain constantly recurring and occasionally lengthened periods of entire stillness, when ventilation is most imperious, they are wholly useless. Employed with some other reliable motive power, the *plenum* and *vacuum* cowls, that is, one facing to the current and throwing the air into the underground flue or other supply channel — the other drawing off the air from the ceiling, are aids which may be collaterally employed at times quite economically, but are never to be trusted to alone.

Mr. Sylvester the ablest and most practised ventilating engineer of England, generally adds a simple form of these at each end of his ventilating current. The New York Public schools have one of each kind; pure air being admitted diffusedly as it enters.

7. *Flues opening for the egress of vitiated air at any point near the floor.* This method of constructing escape-flues, in the expectation that when the apartment is crowded full of warm air the lower stratum will be forced

outward and into them, has often been tried and always results in failure. In the earlier attempts at ventilating the McLean Asylum, this arrangement was well tested. The hot air was admitted near the ceiling, but no intensity of heat would drive it into the rooms to the extent of forcing out the lower, and of course if this action were maintained, vitiated stratum. Our text exhibits the occasional expediency and practicability, especially for the lower classes of insane patients, of opening exit flues at the floor, thence carrying them upwards to the main flue connected with the motive power, or directly down into a common flue passing into the shaft in the cellar.

7. *Discharge flues fail from the absence or insufficiency of the means of supply of fresh air below.* For example, the lately built hospitals for the insane usually have no other means of ventilation, than upward flues in the wall. All the air admitted into the halls and rooms in the season when fires are used, is that from the registers of one or two furnaces to supply twenty to forty rooms. In that period often of considerable duration of too high external heat for artificial warming, while it is yet too low and damp for open windows, the same channel and the cracks and openings of doors, constitute all the places of admission of fresh air! It is singular that the first principle of pneumatics should have been thus often violated. To expect vitiated air to depart when no fresh air can take its place, or, on the contrary, that pure air should enter when the escape is not free and of adequate dimensions, is alike absurd.

When a high chimney or lengthened flue in a lofty building may be relied upon, the constant current may often be produced spontaneously through a small room, by opening a channel from its floor to the cellar. A series of very offensive water closets were rendered quite tolerable by this arrangement. A separate flue to each passed from the floor to the cellar, and another from the ceiling to the attic. The walls having originally been filled with flues, as recommended above, this arrangement was made many years after the erection of the buildings, by piercing and stopping them, as the case required.

B.

The extent of apparatus required in warming by steam and hot water, has been the subject of experiment, and experience of many years in practice, in fact since 1745; the results of which are given by various scientific writers, — Buchanan, Tredgold, Scott Russell, Arnott, Hood, Bernan, &c. Their experience is confined to the climate of Great Britain, and they differ considerably from each other. Yet keeping an eye to the occasional extremely intense cold of New England winters, the approximation may have some value as a basis for any practical undertakings here.

I. *Of Steam Heating.*

The following items of the more useful kind, taken from the table of Mr. Bernan, deduced by him from Buchanan and others, exhibit the practical effect of a given surface of steam pipe or other form of enclosing surface, in

maintaining certain areas of interior at a raised temperature, when the external air was below the freezing point of water.

A square foot of steam-warmed surface kept —

400 cubic feet of space of a			chapel, (cast iron pipes,)	at 60°.
370	"	"	meeting house, "	"
180	"	"	dining room, "	" 64°.
209	"	"	dining room, containing 8,400 cubic ft. 15 feet high,	" 62°.
306	"	"	public room, (cast iron pipe,)	" 54°.
175	"	"	6 cotton mills each containing on an average 205,006 cub. ft. of space (c. i. pipe)	" 80°.
256	"	"	counting house, lighted from ceiling,	" 61°.
243	"	"	average of three do. lighted from side,	" 64°.
140	"	"	average of seven rooms in a public building heated by an ornamental cast iron vase in ea. ¾ in. thick ; greatest effect,	" 50°.
			one of the rooms fitted with double windows could be kept at	" 64°.
266½	"	"	printing office ; 4 floors, average,	" 68°.

For uses requiring a much higher temperature, as for forcing in green-houses, drying rooms, the quantity of surface is, of course, much augmented; for example, in a forcing house, 30 cubic feet of space were kept at 80°, by each foot of steam surface; in drying houses requiring from 90° to 100°, that amount of radiating surface supplied from 40 to 80 cubic feet. As these purposes are not within the scope of the present inquiry, it is not necessary to pursue them.

The application of these elements is obvious. For example, if it be required to ascertain the amount of iron surface for a factory containing 100,000 feet of space, divide this quantity by 175 : the quotient 574.2 will be the number of feet of steam surface which will secure a temperature of 80°, while the external air is below 32°. Or if of a dining room of 5,000 feet space, this divided by 140 will give 35.7 square feet of steam surface to maintain a summer heat. Mr. Bernan remarks that these though rough, are safe practical estimates, which may be applied and depended upon in numerous analogous cases.

Mr. Tredgold's formula for determining the extent of steam pipe, is this: If, for example, 200 cubic feet of air is to be supplied per minute, to a room to be kept at 60°, (external air at 32°,) he considers the average surface heat of the steam pipe as 200° — not 212°, the steam point. Then, if the difference between the required temperature and the external air be multiplied by the number of cubic feet of air required per minute, and the product be divided by 2.1 times the difference between 200 and the temperature of the room, the quotient will be the number of square feet of surface required. Thus $(60 - 32) \times 200 = 5600 \div 2.1\ (200 - 60°) = 19$ square feet of iron pipe or other surface of metal.

The first of these methods omits any consideration of the heat removed by ventilating processes. Mr. Tredgold's omits any reference to the space to be heated. Dr. Arnott takes into view the heat lost by glass windows, by crevices,

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and by openings for change of air. He estimates that in the winter day, the thermometer at 10° below 32°, to maintain a temperature of 60°, there must be of surface in contact with steam, (which surface in actual average practice he also considers as at 200°), one foot square for every 6 feet of common window glass ; as much more for every 120 feet of wall and ceiling of ordinary materials, and the same for every 6 cubic feet of hot air escaping per minute as ventilation, and replaced by fresh air. A window of usual tightness allows 8 feet of air to pass per minute, and there should be allowed at least 3 feet of air a minute, for each person in the room. Thus, suppose a room 16 feet square by 12 feet high with two windows, each 7 feet by 3, and with ventilation by them or otherwise, at the rate of 16 cubic feet per minute.

42 sq. feet of glass requires	1 foot of	steam	surface for every	6 ft.	=7 feet,
1238 feet wall, ceiling, &c.	"	"	"	" 120 ft.	=$10\frac{1}{3}$ feet,
16 feet per minute,	"	"	"	" 6 ft.	=$2\frac{2}{3}$ feet,
					20 feet,

that is, 20 feet of pipe 4 inches in diameter, or other equivalent of metallic vessel.

Let us apply the elements of Dr. Arnott to a common Massachusetts school-house for 100 pupils. The common dimensions of such a school-room would be, say 40 feet long, 22 feet wide, and 12 feet high, containing of superficial square feet of surface, $40 \times 22 \times 12 =$

3248 f. at 120 ft.	for 1 ft.	of	steam	surface,	is	27 ft.
Windows, $7 \times 3 \times 6 = 84$ f. at 6 ft.	"	"	"	"		14 "
Ventilation 100 persons $\times$ 3 f. $= 300$ f. at 6 ft.	"	"	"	"		50 "
						91 ft.

Or ninety-one feet running of 4 inch pipe, a length which would be a little short of passing around at the angle of the floor on three sides of the room. If larger or smaller pipe or if enclosing vessels of other shapes be used, the running length or area will be readily calculated.

The size of the boilers will be fixed by the capacity of the pipes. As much space for steam should be left in the boiler, as is equal to all the steam in the pipes. The space for the water should be somewhat, say one eighth less. In the illustration just cited, to find the size of boilers :

Circum. of pipe.	in a gallon.	
$12 \times 2 \div 2 = 12 \times 12 = 144 \times 91 = 13{,}104 \div 231 =$	56	gallons for steam,
Less one-eighth, for water, . . .	44	
Size of boiler.	100	gallons.

II. *Of Heating by Hot Water.*

The cause of the circulation of hot water in tubes leaving and returning to a boiler is undoubtedly owing to the diminished gravity of the fluid when rarefied by heat. The moving power will depend, therefore, on the difference of distance at which the upper or warm, and lower or cooler pipes are placed from each other, the directness of the current and the heat withdrawn. Mr. Hood says he has known as small a difference as three inches where the pipe was very small, (two inches in diameter,) and free from turns and angles. He however regards a foot as the minimum height which will

obtain a good circulation, where the pipes do not dip below the horizontal level, as in passing doors.

The pipes may be carried over every story of a house. In this case, the boiler must be closed, and made capable of standing the great pressure represented by the widest base at the boiler, and the highest line of the column — a pressure apt to occasion leakage, unless the mechanism of the joints is extremely perfect.

In case the pipes are carried horizontally in flues, or convoluted in air chambers, where no point of the circulation is higher than the level of the boiler, no considerable strength of boiler or of joinings is required. It is not unusual, under these circumstances, to allow the boiler to be covered only with a loose cover, the evaporation from it passing directly into the air flues.

It is by no means necessary that the pipe connecting the radiating tubes with the boiler, should be of full size. Mr. Hood prefers in using four-inch pipes of cast iron (which is his favorite size), that the connections should be only two inches in diameter.

Masses of pipes may be thrown into air-chambers, located at points in the cellar determined by the position of the apartments above to be warmed. In such cases, the difficulty of distributing hot air horizontally in channels, is provided for, and the great advantage of a direct perpendicular supply-flue is secured. The connections between these receptacles of pipes, each of which has its fresh-air channel, may be kept up with the boiler and with each other by much smaller pipes, wound with cloth, or other non-conducting material.

It is common to make the difference of level of the pipes several feet. The height of the basement or cellar, and the form of vertical boilers, with tubular flues, much used of late for this purpose, allow as much variation as the case requires, where no attempt is made to send pipes above.

The quantity of heat removed in the air-chambers or channels containing the pipes, by conduction, is four-fifths of the whole. The remaining one-fifth, distributed to the walls of the containing cavity by radiation, is not wholly lost, since it is again given out to the air when the temperature is lowered.

Where there are various series of pipes leaving the boiler, a regulating cock, or the simple and much superior valve used for such purposes of late, should be added, to regulate the flow as circumstances may require. As the current depends not only on the difference of level, freedom from turns and angles, horizontal or vertical, but also on the rapidity of reduction of temperature, some care is required to regulate the various distributing coils or aggregations, by shutting off a portion of the flow to those where an undue proportion of heat is received.

It is obvious, that the impinging of a full current of extremely cold air upon one series, would reduce the temperature, and consequently the gravity and the activity of motion, much beyond the rate common under other circumstances.

In using the mild hot water apparatus, or that in which the circulating fluid does not rise above 212°, so termed in contradistinction to the method invented by Mr. Perkins in which water may even be heated to a degree sufficient to inflame wood in small strong pipes, the quantity of pipe used is about the same as that employed with steam, and of course the methods of calculation just given may be applied. Mr. Hood, the latest and best writer

on this subject, gives the following rule as more accurate than any means hitherto found for calculating the radiating surface of simple hot water tubes. "Multiply 125 by the difference between the temperature to be produced in the room and that of the external air; divide this product by the difference between the temperature of the pipes and that of the room; then multiply the quotient by the number of cubic feet of air to be warmed per minute; this product divided by 222, will give the number of feet in length of pipe 4 inches in diameter. If 200 cubic feet of air is to be warmed in a minute, and the external air is at 32°, the room at 60°, and pipe at 200°, then $125 \times 28 \div 140 \times 200 \div 222 = 225$ feet of 4 inch pipe required. This multiplied by 1.38 will give the length of 3 inch pipe; by 2 of 2 inch pipe, or four times the length of one inch pipe."

The table following gives by inspection, the amount of radiating surface to produce a given result.

Table showing the quantity of pipe, four inches in diameter, which will heat 1,000 *cubic feet of air per minute, any required number of degrees; the temperature of the pipe being* 200° *Fahrenheit.**

Temp. of ext. air.	Temperature required for the Room.									
	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°
10°	126	150	174	200	229	259	292	328	367	409
12°	119	142	166	192	220	251	283	318	357	399
14°	112	135	159	184	212	242	274	309	347	388
16°	105	127	151	176	204	233	265	300	337	378
18°	98	120	143	168	195	225	256	290	328	368
20°	91	112	135	160	187	216	247	281	318	358
22°	83	105	128	152	179	207	238	271	308	347
24°	76	97	120	144	170	199	229	262	298	337
26°	69	90	112	136	162	190	220	253	288	327
28°	61	82	104	128	154	181	211	243	279	317
30°	54	75	97	120	145	173	202	234	269	307
Freezing 32°	47	67	89	112	137	164	193	225	259	296
34°	40	60	81	104	129	155	184	215	249	286
36°	32	52	73	96	120	147	175	206	239	276
38°	25	45	66	88	112	138	166	196	230	266
40°	18	37	58	80	104	129	157	187	220	255
42°	10	30	50	72	95	121	148	178	210	245
44°	3	22	42	64	87	112	139	168	200	235
46°		15	34	56	79	103	130	159	190	225
48°		7	27	48	70	95	121	150	181	214
50°			19	40	62	86	112	140	171	204
52°			11	32	54	77	103	131	161	194

Find the external temperature in the first column, and the required temperature of the room at top; the number at the intersection of these columns will represent *the number of feet* of four inch pipe.

The principle which fixes the size of boilers in the hot water apparatus has no analogy to that in steam boilers. The size of boilers is based upon the quantity of fire surface which may be thought necessary to keep the water heated; — the greater this surface in reference to the capacity of the pipes and the less the quantity of water, the sooner it is heated. Of course the

* Hood on Warming Buildings, page 97

boilers are best, made of a shape in which the under side is concave or reverberatory, and the top and bottom distant only a few inches from each other. The nature of the fuel will influence the extent of boilers. Mr. Hood says, that one square foot of boiler surface exposed to the direct action of the fire, will be sufficient to supply the necessary heat to forty superficial feet of pipe, or other radiating surface. This, he observes, is a very good proportion, suitable for nearly every purpose. This is a considerable reduction from the maximum, which is about 50 feet of pipe to the foot. This however makes an apparatus much easier managed, and more effective and certain than where only the extreme is calculated upon. He gives the following table as deduced from the allowance of one foot of direct boiler surface to 50 feet of radiating surface.

	Feet 4 in. pipe.	Feet 3 in. pipe.	Feet 2 in. pipe.
4 square feet,	200	266	400
6 " "	300	400	600
8 " "	400	533	800
10 " "	500	666	1,000
14 " "	700	933	1,400
20 " "	1,000	1,333	2,000

In modern practice, the forms of boilers filled with small tubular flues, like those of the locomotive engines, are much employed for steam and hot water warming.

While I have thus adduced the latest and most practical foreign authorities as to the quantity of steam-warmed, or hot-water-warmed metallic surface adequate to produce a satisfactory temperature, under different circumstances, I cannot conceal my conviction that the great element of calculation is so essentially changed in the climate of New England, that our knowledge of the extent of apparatus to heat adequately private or public houses must be reached in an entirely different method. This element is the prodigious reduction of temperature during our winters, not infrequently reaching an extreme, for days, so much below the experience of Great Britain, as certainly to render nugatory any calculations based on the results of experience in that country. It must not be forgotten, that any provision for heating must be capable of meeting these extraordinary cold seasons. However well all average conditions might be fulfilled, no apparatus not fitted for the ultimatum of New England winter cold could be tolerated, except provision were made in other forms of heating, to aid in the extreme emergencies.

In advising the extent of apparatus of these kinds, I have been disposed to throw aside the experience of other climates, and proceed tentatively until an experience, precise and definite, of our own shall be attained. It is easy to contrive arrangements by which pipe, whether for steam or hot water, shall be added successively in the air-chambers, until the exact point is reached. The furnaces for anthracite, especially, and for any fuel, can be made so as to admit of a very considerable increase of the usual amount of consumption, both by increasing the draught and by enlarging the grate.

If the heating is by steam, a second boiler can be added, if the additional quantity of pipe required in the air chambers cannot be supplied by the first.

The only objection to these successive additions is, provided the probability or possibility of future additions is kept in view from the first, the difficulty of

making estimates or contracts for the proposed heating. As, however, the most common uses on a large scale will for some time, at least in this country, be for hospitals and institutions, where, if well done, the question of cost is quite secondary to that of hygienic perfection, the method of providing by contract will not be likely to be selected, until a greater amount of experience is aggregated, it is not much to be regretted that we must reach our end in this way, by trials.

In our climate, I should prefer to form a judgment of the quantity of apparatus, by a comparison drawn from the amount of fuel used in the common way, rather than from the best data now accessible. The same quantity of fuel containing (if its combustion is equally perfect), as much caloric when used through one medium as in another, it would not be difficult to adapt the fire surface to meet the estimated quantity of fuel to produce a certain result, if consumed directly.

For example, if a hospital was known to use a given quantity of anthracite or bituminous coal or wood per annum in hot air furnaces, it would be safe to have the boiler or heater grates made on a scale to consume the like quantity. This estimate would be controlled by any influencing circumstances, such as a more extensive waste in ventilation, a less escape at the point of combustion, &c., which might seem to demand a greater or less quantity of warming material. It is of course not pretended that the methods recommended of steam or hot water warming, are the most economical. It is the quality, rather than the quantity of the heat which constitutes their superiority. Still, however, there can be, from the nature of things, no waste in fuel, circumstances of waste being the same.

It fortunately is true in practice, that the size of the hot air chambers in which the radiating surfaces are enclosed, is quite an immaterial consideration. It may be made sufficiently large to admit twice or three times as much tube as may at first be thought adequate, without any loss of advantage, in case increased quantities are added.

In practice, the shape in which the radiating surface is arranged is a matter of considerable moment. Pipes are much more conveniently connected than plates or more solid forms, and those of 3 and 4 inches are more convenient than larger sizes, so that it is preferred to use a double small pipe, (which also allows one set to be disconnected by cocks), rather than a larger single one.

Of late years, welded iron tube of ¾ to 2 inches is much used for steam and hot-water warming, as well as for many purposes for which lead pipe was formerly used. It is much cheaper than lead, for pumps, aqueducts, &c., where any considerable amount of pressure is to be provided for, and has as regards the conveyance of water for household uses the decisive advantage of involving no unpleasant or injurious consequences to those using it. The frequent poisonings from water conveyed in lead pipes, although doubtless to be explained chemically as ascribable to peculiar circumstances not touching all waters, cast a distrust and a sickening suspicion over its employment, entirely forbidding its adoption while this better method is at hand. The joinings are by screws, a *jacket* with a female screw uniting two lengths, a little white and red lead in oil being used. These pipes cost from 12 to 15 cents per foot for inch diameter. The cost of large cast iron pipes of 3, 4, or 6 inches diameter, will be found per foot of outside or radiating surface, to be considera-

bly less. The pipes cast for heavy heads of water can often be obtained, in consequence of their thinness, for their value as raw material. As the pressure of steam or hot-water heating is never more than one or two atmospheres, these fully meet every requisite.

Steam and hot-water pipes are connected in the same way. This is done by flanges brought together by screws, with some suitable substance, as pasteboard, rope-yarn, or felt, covered with white or red lead in oil. This is a usual joint for steam under great pressure. The socket joint in which the end of one tube is enlarged for a length about equal to its diameter, and the next one inserted therein and the intervening space filled up with iron-cement is a much neater and equally strong process. After the iron cement is thoroughly dried, it becomes as strong as the iron itself.

The iron-cement for these junctions, as well as other purposes in steam and hot-water apparatus, is compounded in various ways — the main ingredients being sal ammoniac, iron filings or turnings, and sulphur.

Mr. Buchanan's recipe consists of 40 parts by weight of iron borings, to 1 part of sal ammoniac, and half a part of sulphur, well beaten together. As much sulphur renders the composition brittle, a smaller proportion is advisable, when no haste is required to admit the steam.

Mr. Peckstone gives the following directions. Take 1 lb. of iron borings, pound in an iron mortar until they will pass through a fine sieve; mix two ounces of powdered sal ammoniac, and one ounce of flowers of sulphur. Mix by rubbing in a mortar, and add water to a proper consistency, to be set up with a blunt caulking iron into the space between the pieces.

The French prescription for this important material, as given by Péclet, is one hundred parts iron turnings, two of sal ammoniac, one of flowers of sulphur, and half a part of sulphuret of antimony, to be mixed with urine enough to cover it. It will not attain its hardness for some days.

A packing of hempen rope smeared with a mixture of red and white lead in oil, and driven in with a caulking iron, also makes a secure and permanent joining for steam and hot water tubes.

In arranging pipes for heating by steam or hot water, it must not be overlooked to make an allowance for expansion of ⅛ of an inch for every ten feet of pipe. A *drip* pipe to carry off the condensed steam is also necessary, unless the tubes are so raised at their farther extremity as to allow this to run back to the boiler.

Nor in hot-water pipes must be overlooked the tendency which air has to become impacted at some point of the circulation and thus prevent the whole current. It is safe on this account to have every elevated point, and every alteration of level of the pipe fitted with an air pipe rising as high as the level in the boiler, and provided with valves or cocks to permit the tubes to be freed from this embarrassing obstruction.

There are practical difficulties in carrying hot-water pipes to several stories in height, arising from the pressure of long columns of water straining the joinings and endangering leakage, which, in most cases, renders it usually more advisable to place the pipes in ranges in an air chamber in the cellar below to which the air is admitted by a flue from without, and drawn out in upright flues. The air chambers may be elongated in order to carry the air horizontally to any distance, or made at convenient points as respects delivery above, and the connection with the boiler kept up by simple

smaller pipes, protected from waste of heat by non-conducting coverings. In the new Penitentiaries at Wakefield, the upright flues withdraw hot air successively for some hundreds of feet. The only loss is from the conduction of the sides of the air flue, in which the hot-water pipes are suspended.

In the warming of the Massachusetts General Hospital, the water pipes are made of thin copper tube, about one thousand feet in length for each wing, and four inches in diameter, placed in air chambers.

I have been induced to go somewhat minutely into the detail of the methods of heating by steam and hot water, from several considerations. I know of no American work or reprint which contains any information on the subject. This mode of heating for health and luxury is vastly superior to any other, whether in public or private buildings, occupied by persons for any length of time. The fire-proof character it gives to buildings is important, and in public buildings for libraries, the fine arts, and the like, can scarcely be overestimated. The methods are simple, and were the mechanical fittings as well understood with us as they are in Europe and ere long will be here, a true economy would permit a very wide use of this elegant, convenient, and healthful addition to the comforts of civilized and refined life. So far as consumption of fuel is concerned, it is obvious that there can be no loss as compared with other modes, beyond the trifling expenditure of radiated heat at points, as the cellar, where it is not available. By the use of non-conductors around the steam and water boilers and pipes, this is reduced to a trifle. The waste of fuel by the chimney is better prevented than in most furnaces; and that serious drawback upon all modifications of hot-air furnaces, calorifers, or stoves furnished with fresh air from the outside, or even open grates and fire places — the escape of occasional or constant quantities of smoke, gases, and impalpable powders — is unknown.

The mechanical knowledge of steam power, of cast iron and other branches of metals, has become so general in this Commonwealth, that but little difficulty can be experienced in appropriating the delightful and hygienic advantages of the unequalled atmosphere thus produced, if a directing mind can be found to assume the responsibility and oversight of the needful fittings. Feeling much hope that this healthful mode of warming school-houses and other inhabited buildings by pure air warmed by contact with hot-water and steam tubes, may become general, as the facility and cheapness of providing the necessary apparatus are augmented — as they cannot but be with the advance of the community in the mechanical arts — another circumstance of detail may be of importance, especially to those who may have apprehensions of the safety of such measures under all circumstances, which persons of no practical acquaintance with the management of steam and heated water may naturally enough be presumed to feel. A closed boiler, although intended to be subjected to no strain or to the most moderate pressure only, may by carelessness or accident be subjected to a much greater or a dangerous force. The safety-valve, that simple and efficacious protection, may from neglect cease to act, or it may be secured by ignorance or mischief, so as to be a protection no longer. Again, the supply of water, so essential to safety, may be omitted.

With the possibility of a contingency like this occurring, few persons would feel safe in trusting a boiler large enough to warm a common school-house,

for instance, in the inexperienced hands which alone can be expected to manage such an apparatus in such a position.

It may be satisfactory to any who might, with this source of anxiety removed, be willing to introduce this beautiful method, to be assured that there is an additional mode of guarantying the safety of boilers from explosion, exceedingly cheap and simple; which we have the high authority of the most eminent writer on this class of subjects, Mr. Péclet, for saying, offers a complete efficacy against dangerous pressure.

This consists in the application of a plate of fusible metal to a hole in the upper part of the boiler, to which the steam has direct access. As the pressure of the steam increases, its heat augments in a certain well known proportion. The readiness with which the metal melts depends on the proportion of the ingredients, lead, tin, and bismuth, of which the plate is composed. A plate prepared so as to fuse at a point considerably below the proved strength of the boiler, would promptly become melted, giving free escape to the steam and preventing all hazard.

A royal ordinance in France prescribes the various points to be regarded in these safety plates, two of which must be placed to fuse at different temperatures on every steam boiler.

The plates should be of the same size as the area of the safety valve, and as they are liable to be swelled out at a lower point than that of fusion, and might be ruptured, they are covered on the outside by a perforated plate of iron, which of course gives no obstruction to the issue of steam, when the fusible metal has yielded to its expected heat. The arrangement is this:— A hole as large as the area covered by the safety valve, is bored into the top of the boiler; the fusible plate, one half to one inch thick, is placed over it with the usual cement to make a tight joint; the perforated iron plate or grating, is placed above and screwed at its outer edge to the boiler, thus confining the plate.

The following table gives the proportion of the metals to be alloyed together to resist the heat produced by steam at various pressures, of from one to eight atmospheres, or from fifteen to one hundred and twenty pounds to the inch. The last pressure is of course as much as will ordinarily be employed as a maximum in steam boilers.

Number of Atmospheres, each 15 lbs. to sq. inch.	Corresponding temperature of the Steam.	Actual temperature at which the alloy melts.	Proportions of the fusible alloy in parts.		
			Bismuth	Lead.	Tin.
1	100.	100.	8	5	3
1½	112.2	113.3	8	8	4
2	121.4	123.3	8	8	8
2½	128.8	130.	8	10	8
3	135.1	132.4	8	12	8
3½	140.6	143.3	8	16	14
4	145.4	145.4	8	16	12
5	153.8	153.8	8	22	24
6	160.2	160.2	8	32	36
7	166.5	160.5	8	32	28
8	172.	172.	8	30	24

The temperatures are here given by the Centigrade standard, the proportions of which to Fahrenheit's, are as one hundred to one hundred and eighty, or as five to nine.

As a means of saving calculation, the following table of the contents of tubes of various diameters is given.

Diameter of pipe. Inches.	*Contents of* 100 *running feet.* Gallons.
½	.84
1	3.39
1½	7.64
2	13.58
2½	21.22
3	30.56
4	54.33
5	84.90
6	122.26

The question whether large cast iron or small welded tubes should be used for steam or hot-water circulation, is readily determined by the relative economy of providing a given amount of radiating surface in each.

Where a steam pipe over four inches in diameter is used, it is said, that the difference of temperature in the upper and under portions, and, the consequent irregularity in expansion, gradually produces an upward curvature endangering the soundness of the joints.

In all steam or hot-water pipes, provision for the expansion and contraction is readily made. If the pipe is of large diameter it is suspended by chains or on rollers. If small, slipping joints with a screw collar, like the ordinary stuffing joints, are used. Or a bend in the pipe at one or more places, like the letter U, enables the two upper portions to be closed together or drawn asunder without disturbing the connections of the tubes.

C.

The plan recently proposed, and now in process of completion, for the heating and ventilation of the male side of the McLean Asylum for the insane at Somerville, Mass., is predicated on the experience of the English examples, and is arranged on Dr. Reid's general principles. It is considered as worth description, from its having some distinguishing peculiarities in its arrangements.

The building is in the form of a T, with the perpendicular line at an oblique angle (see Fig. 18, Pl. IV.) The two portions having been built at different periods, were unfortunately connected by the end of the earliest being inserted into the new portion, making a dark and unventilated interior, which it has been the object of recent designs to remove. The horizontal part is 90 f. × 40, and the diverging or old portion 80 f. × 40, each of three stories, and consisting of a gallery running the whole length with the day rooms,

dormitories, water-closets, &c. opening upon this central corridor. About ninety patients and twelve or fifteen assistants are accommodated in it, with the aid of some attic rooms and a separate lodge building.

The heating in former years has been accomplished with various forms of hot-air furnace, and the ventilation in the spontaneous method of late years, that is, by flues opening from the rooms and running up to the garret, whence the foul air escaped by chimney cowls turning to leeward. The earlier attempts referred to in a different part of this Appendix proving wholly nugatory, without a motive force which could not be readily devised, had been converted as far as possible into the simple escape flue from the ceiling; in more pressing cases, as in water-closets and lodge-rooms, these were aided by induction flues, running from the floor directly down into the cellar. It is hardly necessary to say, that under all the unfavorable circumstances of construction, size of flues, use of hot-air furnaces and absence of moving power to exhaust the foul air, the condition of the building as respects an abundant supply of pure, gently warmed air, was like that of all the other insane hospitals of New England, which are all furnished in the same manner, exceedingly imperfect and behind the age.

Years of consideration have elapsed without there appearing to be any way of overcoming the difficulties presented by the original omissions in the construction. The lighting was imperfect, and the heavy brick walls forming the partitions and resting in part on heavy groined arches below, could not be perforated with new flues of proper number and size. The interior walls supporting the attic story of the center and the dome, forbad the idea of any upward ventilation with motive power, as it would require the power to be in four distinct sections under the roofs, which could not be connected without sacrificing a considerable number of rooms and passages necessary for the accommodation of the patients and their due classification.

Under these complicated and embarrassing difficulties, the following arrangement was suggested, as that which would best meet the necessities of the case; — that about fifty feet of the centre of the front building should be eviscerated, and gallery walls be built up continuously so as to extend the corridor at a uniform width from end to end, and in these by a proper thickness of walls to furnish as many hot-air and foul-air flues as were required.

A large space, which in consequence of the peculiar twist and insertion of the wing, could not be lighted or otherwise made of value, and which was at the most central point of the two sections, was devoted to the use of a ventilating shaft. The ventilating shaft commences with a circular interior of about six feet diameter, and gradually tapers to about one half the bottom area. The entire height of the shaft is over seventy-five feet. The boiler for the hot water for heating was placed near this, and the smoke chimney of cast iron pipe, runs up until within about ten or a dozen feet of the top, when the foul-air shaft begins to be contracted to give impetus to the current at its exit. Here the smoke and gases of the chimney are to be delivered into the shaft.

The pure air is admitted through a long under-ground flue of about twenty feet area, terminating in a short tower, which was originally used to supply the hot-air furnaces. From the cellar, openings are made every few feet to permit the air (the current of which, often troublesome when the winds

are strong, is checked by being admitted into the open space or reservoir, as it were) to enter the long horizontal box or air channel divided into three divisions, each of which supplies a story of the house, and each has a couple of hot-water pipes, of large size, connected with the perpendicular boiler by small tubes. These circulate the water the whole length of the cellar, under the central corridor on the one side, and bring it back to a lower point in the boiler on the other, a distance of about one hundred and twenty feet. The partition into three channels was considered indispensable to make an independent heating and ventilation for each story, as it ever has been found impossible so to regulate air flues leaving the same chamber and opening at different heights, that there shall be a reliable uniformity in different stories.

The pure air enters all these channels in the cellar at orifices commanded by lids or registers, and each one of them delivers its heated air through the flues opening from its superior surface into the story for which it is designed, uninfluenced by its neighbor.

The warmed air is delivered *near the ceiling*, at quite a number of orifices in each corridor, and in those rooms where it was thought it would be required, and in as free openings as the space would allow. The foul-air flues commence near the floor of each room or gallery, and descend to the cellar floor in the wall. At a point opposite the ventilating shaft, the joint flues are turned by the shortest course so as to open beneath the foot of the shaft.

One of these foul-air flues is to be turned beneath the heating boiler so as to supply its air of combustion.

A little reflection will show that the objects of this apparently complex, but really perfectly simple arrangement are,

1. To destroy the effects of currents connected with the direction and force of the wind, by receiving the air into a reservoir.

2. To admit it in various places to the hot-water tube, and discharge it in each story at openings a few feet distant from each other, so as to produce a general diffusion.

3. To make the heating and ventilation of each story entirely independent of each other from the point where the air enters to its discharge.

4. To admit the heated air at the ceiling, and draw it off at the floor, to obviate the peculiar difficulties in insane hospitals from a reverse of this movement.

Precisely the same arrangement connected with the same ventilating shaft and the same boiler, will be necessary for the projecting wing.

Fig. 18 represents a plan of the male side, but the heating and escape flues are necessarily to avoid confusion, represented rather as a diagram, than as an actual plan. Fig. 19 is a cross section at the point noted in the ground plan by the dotted line. The warmed air is here figured by the solid lines and arrows entering the tri-partite wooden channels, *a a;* after impinging on the hot-water tubes running within, it passes in the corridor wall, and is delivered at the ceiling ; — the foul air, represented by the dotted line, descends at the floor, passes down in the wall, crosses into the drain at the bottom of the cellar, passes along that until near the shaft into which it ascends. The ground plan represents the course of the foul air from the rooms to the shaft.

The great number of warm and foul air flues, on each side of the corridor,

and each pair fulfilling the purpose just described, could not be represented on so small a scale.

Dampers are inserted at such places as are convenient to control the ingress and egress of the air. It has been within the purview of this adaptation, to carry an additional hot-water circulation into such portions of the wing, as from their occupation by cleanly and convalescent patients, do not require to have all the heated air used, and which is wasted, if not so required by passing off in unneeded ventilation.

The escape steam from the steam pump used to elevate the water used, will be turned into the centre of the shaft, to add to the motive power.

Fig. 19, Pl. iv. represents a section of the male wing at the point denoted by the dotted line *b*, of fig. 18; *a a*, are the longitudinal hot-air chambers in the basement, divided into three sections, one for each story, and enclosing the four inch cast iron water tubes; *b*, is the upright tubular boiler in which the extremities of the tubes enter at top and bottom, a difference of level of five or six feet; *c* is the exhausting shaft represented in plan at *a*, in Fig. 18; *d* is the foul-air drain, opening beneath the shaft, represented in plan by *c*, of fig. 18. *d* and *e*, of fig. 18, indicate the position of the hot-air chambers and water pipes, at the foot of the partition containing the ascending and descending air flues. For perspicuity, only a single pair of induction and eduction flues to each room are figured. It is obvious that in view of the several stories, a horizontal section would show a great number of flues. The dotted lines show the course of the foul air, the solid lines that of fresh air, each room of course having a flue of either kind.

The actual arrangement of the channels in the cellar for the hot-air and foul-air flues to terminate in, is not represented as it actually is, in the plate, for fear of obscuring the illustration of the principle. Fig. 25, pl. iv. is a cross or end section of the actual construction; *a a* is the partition wall separating the corridor from the side dormitories, as it appears in the cellar; H H H are the hot-air channels supplying the three stories respectively; V V V, the ventilating flues coming from the stories. The lower arrows show the course of the foul air as it enters the channels terminating under the shaft.

The upper arrows represent the fresh air entering from the reservoir impinging against the hot-water tubes, and then ascending by the perpendicular flues.

The registers slide before these openings, and are readily commanded through shutters left at convenient places in front.

The same arrangement is provided on the other side of the corridor.

The water-closets, bathing-rooms, &c, have the same downward ventilation as the galleries and dormitories. The shaft terminates in one of four chimney stacks, standing on the corners of the foundation of the dome.

D.

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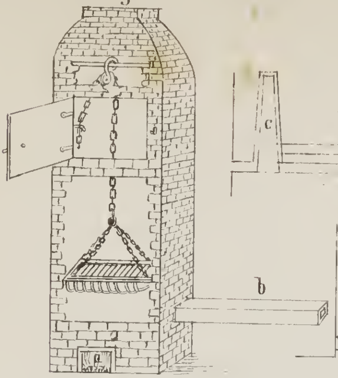
Fig. 1.



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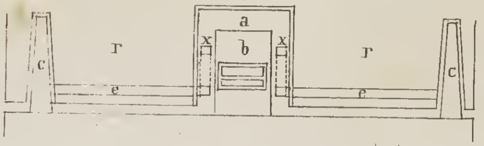
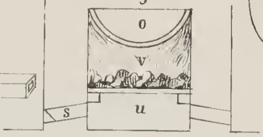


Fig 3.



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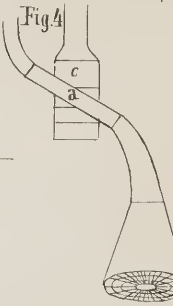

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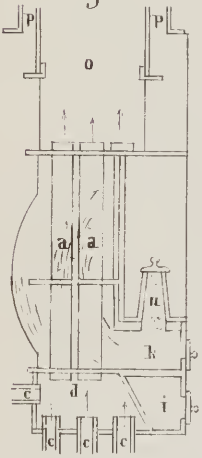

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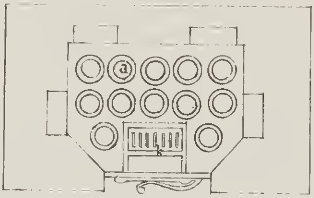

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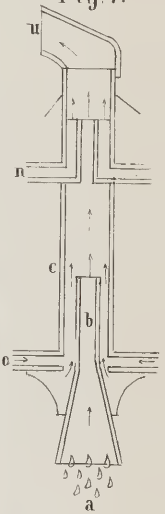

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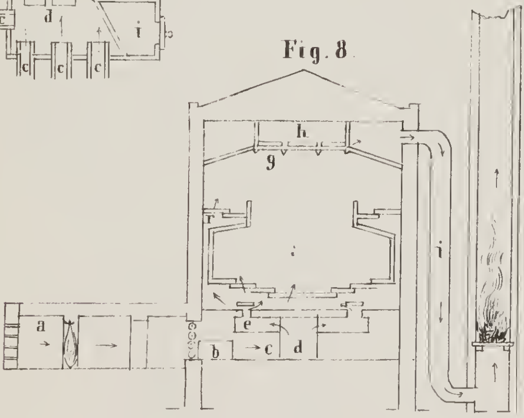

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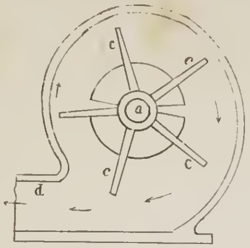
Fig. 22.



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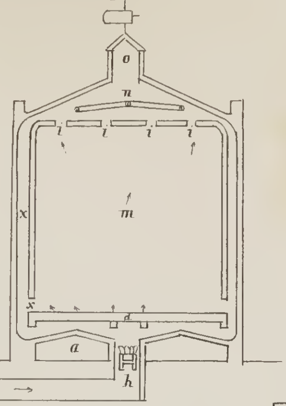

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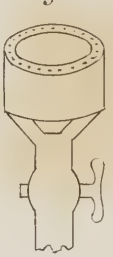

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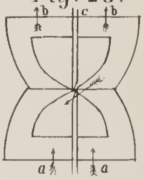

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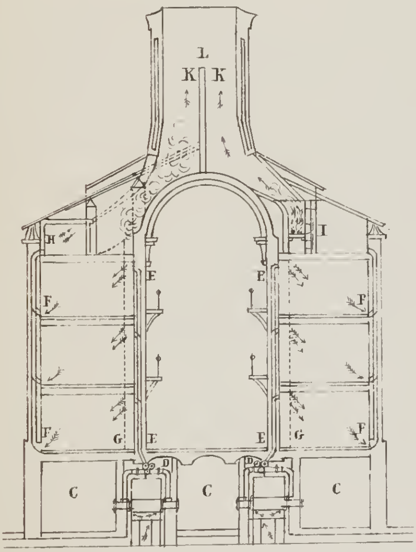

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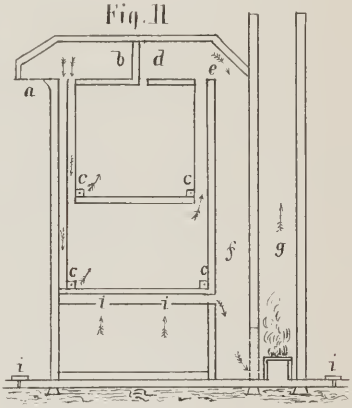

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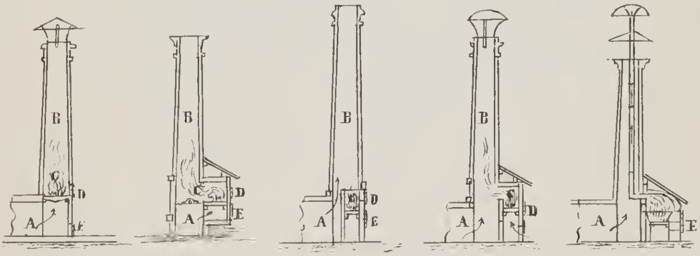

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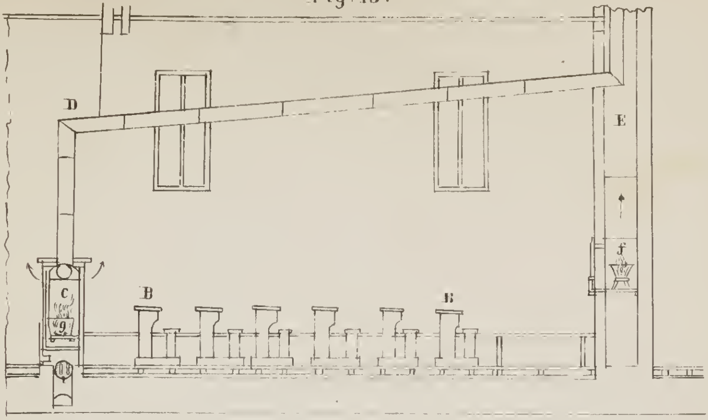

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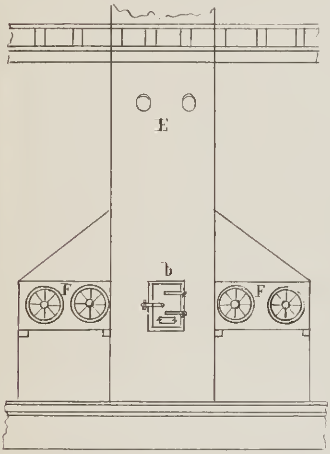

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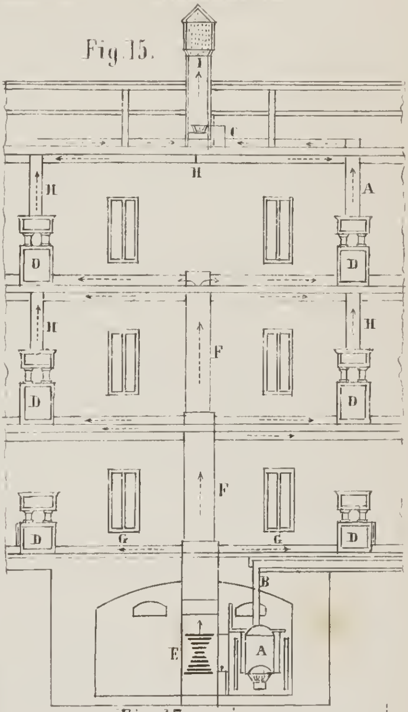

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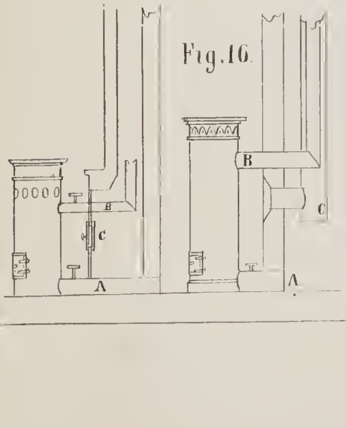

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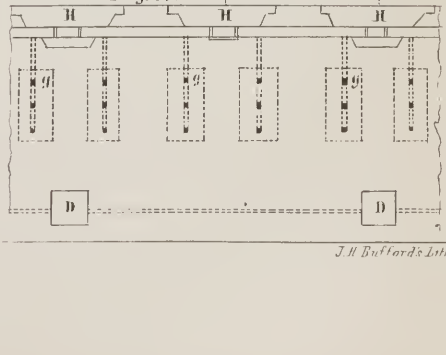

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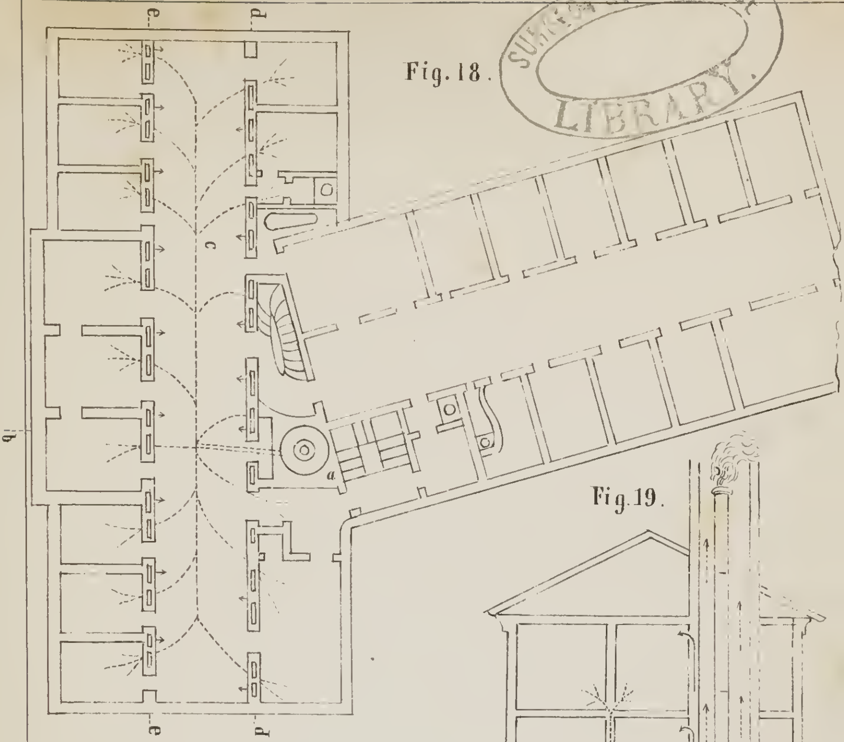

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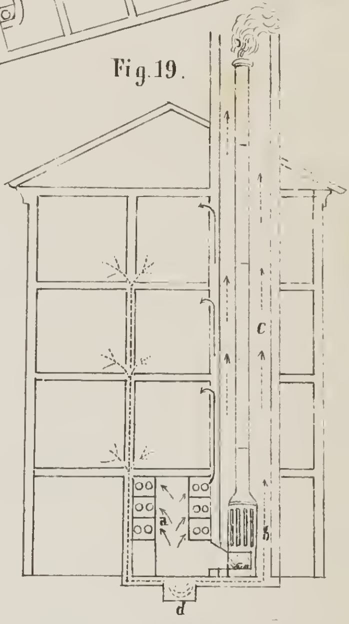

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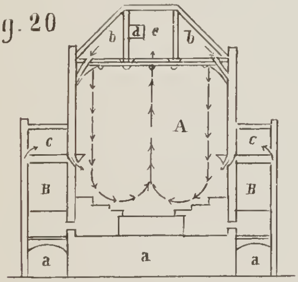

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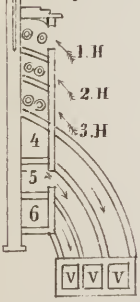

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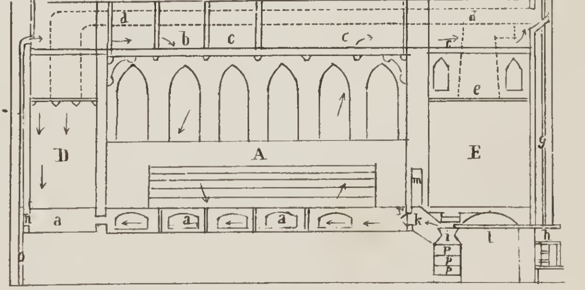

Nelson S. Gorle

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